A MANUAL

OF

ANIMAL PHYSIOLOGY.

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OF

ANIMAL PHYSIOLOGY,

FOR THE USE OF

NON-MEDICAL STUDENTS;

WITH

AN APPENDIX OF QUESTIONS

FROM VARIOUS EXAMINATION PAPERS, INCLUDING THOSE FOR THE B.A. LONDON FOR THE LAST TEN YEARS.

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TO

EDWARD CLAPTON, M.D. LOND.,
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ASSISTANT-PHYSICIAN TO ST. THOMAS'S HOSPITAL,

IN REMEMBRANCE OF MUCH KINDNESS, AND AS A TOKEN OF RESPECT,

THIS VOLUME IS INSCRIBED,

BY HIS OBLIGED FRIEND,

THE AUTHOR.

PREFACE.

THE object of the Author, in compiling the work he now submits to the public, is to present to the *non-medical* student a book, by means of which the acquirement of some knowledge of Physiology may be rendered comparatively easy, and "to economise the time and labour of those who are compelled to prepare themselves for examination on the subject, by collecting into one volume the information they would otherwise have to obtain from various sources."

To persons totally unacquainted with even the rudiments of Anatomy the study of Physiology must be particularly difficult, and to meet this difficulty the Author has endeavoured, in the progress of the work, to introduce an amount of anatomical description sufficient to enable the student to understand the nature of the functions performed by various parts of the body, and the laws which govern their actions; it has also been his endeavour to avoid the employment of too

many technicalities, and to proceed with the description as though he addressed those who were entirely unacquainted with the science; and he, therefore, has used no such expressions without explaining their meaning the first time they occur.

To non-medical students, the acquirement of physiological knowledge must be difficult for another reason—most works on the subject are either of a very abstruse or of a very elementary character. In the former it is presumed that the reader has a considerable knowledge of Anatomy, and the latter are usually of too superficial a nature to supply the information required for a university examination.

In carrying out his plan, considerable difficulty has been encountered by the Author. It was necessary to enter into some details of Comparative Anatomy and Physiology, as well as the Anatomy and Physiology of the Human Body; and the difficulty arose from embracing in so small a compass a subject so extensive. Moreover, it was far from easy to give in a few words a description that would be perfectly intelligible, when such description might much more readily have been extended to some pages. But if the Author has succeeded in making himself clearly

understood, he considers that his object is fully accomplished.

This brief notice cannot be concluded without reference being made to the names of those writers whose works have been largely and constantly consulted during the progress of this treatise; amongst them may be mentioned Bowman, Brewster, Carpenter, Cuvier, Milne Edwards, Ellis, Grainger, Huxley, Jones, Kirkes, Quain, Sharpey, Solly, Todd, Wilson, and many others.

16, Dorset Terrace, Clapham Road;
December 13*th*, 1862.

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NOTE.

In the table on page 25 it was not deemed necessary to separate the Batrachians from Reptiles generally, but the more modern classification is adopted on page 232, where the Vertebrata are divided into five classes—Pisces, Amphibia, Reptilia, Aves, and Mammalia.

ERRATA.

Page 13, line 8, *for* a dorsal and two lateral blood-vessels, *read* a dorsal, a ventral, and two lateral, &c.

Page 17, line 33, *for* without a tail, *read* with or without a tail.

Page 42, line 9, *for* Amphibia, *read* Reptilia.

ANIMAL PHYSIOLOGY.

INTRODUCTION.

ANATOMY teaches the arrangement and relation of the various parts of an animal frame; Physiology refers more specially to the phenomena that are exhibited, and the changes that take place in a living body. The science of Physiology, therefore, treats of laws which govern the functions of organized beings, and the changes that occur in their structure during their period of existence.

Many of the laws applied to Physiology, are equally applicable to other branches of science; and the forces acting in the body that can be accounted for by these laws, are termed Physical, whilst forces that act in the animal frame, which cannot be explained by Physical science, are called Vital.

Many physiologists consider that Vital power is totally distinct from any Physical force; but as several phenomena exhibited by living beings, and formerly ranked as Vital, have, since the advance of scientific knowledge, been reduced to, and accounted for, by known Physical laws, it is most probable that all vital action is merely the result of Physical and Chemical agencies operating in the living body. However, till certain changes and actions taking place in organized structure can be elucidated by Physical science, they must be considered as Vital, though

doubtless, many of them will hereafter be removed from their position, and ranked merely as Physical.

Force, whether Physical or Vital, must, to be appreciable to our senses, exert its influence on some material body; and the consideration of the nature, structure and composition of *matter* will first claim attention.

All existing objects may be divided into two great classes—those that are possessed or capable of life, and those that are not; the former, are termed Organic, and the latter, Inorganic bodies. The distinguishing marks that present themselves between the two classes are, a difference, firstly, of chemical composition; secondly, of form; and thirdly, of the mode of increase.

1st. The elements most commonly met with in the Organic world are, Oxygen, Hydrogen, Nitrogen, and Carbon, which together form compounds, known under the name of *Protein;* but in the Inorganic, a large number of elementary bodies is found, and an almost endless variety occurs in their combinations.

2nd. The form of Organized beings is definite, bounded by curved lines, presenting convex surfaces; whereas that of Inorganic bodies is indefinite, bounded by straight lines, presenting plane surfaces.

3rd. The mode of increase in an Organized being is interstitial, or from within, but in an Inorganic body the increase is from without, by mere external deposit.

Every living being is continually undergoing a gradual change, by the removal of certain portions of its body, and the addition of new ones; and that this continual change may proceed, it is necessary that the body should have some definite organization or arrangement and relation of parts, which, when viewed separately, may be found to differ considerably from each other, and give no idea of the being to which they belong, unless they are considered in the relation in which they stand. Moreover, the whole

is affected by a certain vital influence, and so long as it continues, the changes in the body go on, but, at a certain period, all beings lose this influence and die.

Proceeding with the view of the Organic world, we find it capable of division into two great kingdoms —the Animal and Vegetable; no single characteristic mark can be laid down by which these two may be distinguished; the structure, indeed, of some of the lowest types of animals renders it difficult to say whether they belong to that or to this kingdom; a difference of chemical composition and of nutrition is most marked; for the most part, *Protein*, or as they are termed, "quaternary" compounds, are confined to animals, and "ternary" to plants, the latter being destitute of Nitrogen. This, however, only holds good as a general rule, as some vegetables contain Protein. Motion furnishes no certain distinctive feature, some animals being without that power, and some plants being capable of movement.

The possession of a mouth and digestive cavity is common to the former class, and roots to the latter; plants, too, being fixed, obtain their nourishment on the spot; but animals are usually provided with the means of locomotion, enabling them to seek their food, which in their case is composed chiefly of organic matter; whereas plants subsist on inorganic substances. The possession of a nervous system would be a strong distinction, but as this cannot be traced in all animals; and as certain plants appear to possess something approaching nervous irritability, it cannot be depended on as a certain guide. Nutrition and reproduction are the characteristics of the vegetable, and a tendency to the development of sensation and voluntary motion of the animal creation.

Animals are composed of a variety of different parts, which bear distinct relation to each other, and have certain functions to perform; these parts varying greatly from each other, if viewed separately, present no resemblance to the whole body of the animal

to which they belong; but, in a plant, the various parts are mostly repetitions on the same plan, any one of them being taken will be found to bear considerable resemblance to the others.

In the animal economy the following are the most important characteristic organs:

1st. *A digestive cavity or stomach* for the purpose of digestion, in which the food undergoes certain necessary changes previous to its being taken into the system.

2nd. *A system of vessels or lacteals*, for the purpose of absorption, into which the fluid products of digestion are received.

3rd. *A second system of vessels* or blood-vessels, which receive the nutritive fluid from the first system of vessels, and distribute it through the body by what is termed circulation.

4th. *A respiratory apparatus*, in which the circulated fluid is exposed to the agency of the atmosphere (in the case of aquatic beings air in water).

5th. *A glandular apparatus*, by which certain products in the circulating fluid are rejected or retained for the nutrition of the body.

6th. *A nervous system*, exerting its influence over all the functions.

Lastly, organs of reproduction.—Only the higher animals possess this complex organization; and as we descend in the scale of creation, one or more of these organs will be found wanting.

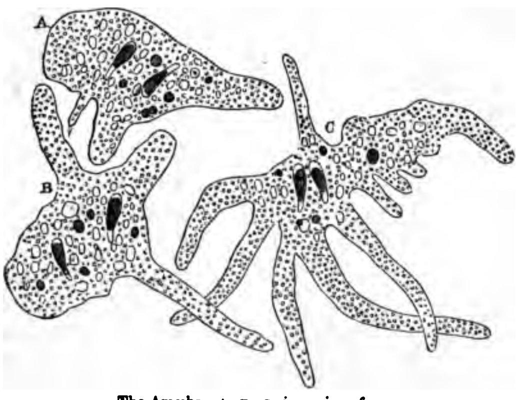
GENERAL VIEW OF THE ANIMAL KINGDOM.

CUVIER divided the animal kingdom into four great sub-kingdoms, the Radiata, Mollusca, Articulata, and Vertebrata; the first containing beings of the lowest,

and the last comprising those of the highest organization. The Radiata, however, included many creatures that could not then be classed under any other head; but as the knowledge of animal life advanced, one by one they were removed from this sub-kingdom, and placed in others, till at length the Radiata was itself replaced by two fresh types, the Protozoa and Cœlenterata.

The PROTOZOA comprises the lowest forms of animal existence, and is divided into two classes, Astomata and Stomatoda, or those that have not, and those that have mouths.

As an example of the *Astomata*, we may take the Amœba, a mass of jelly-like substance (found in pools



The Amœba: A, B, C, in various forms.

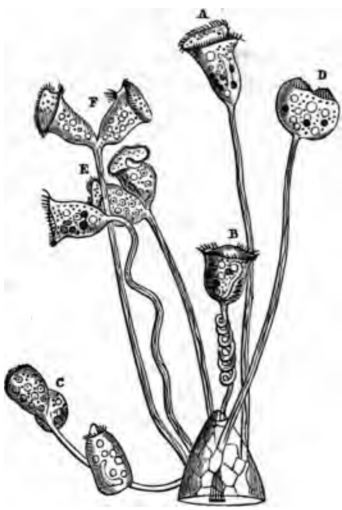
and stagnant water), with no definite form, and without a mouth or alimentary canal; capable, however, of prolonging *any* part of its body into arm-like processes, which seize and enclose its food. In the same way, any part of the body seems to have the power of dissolving substances brought into contact with it; and the food having been digested, the refuse is

§

permitted to escape by an alteration in the creature's shape, the processes being withdrawn from around the indigestible matter. Throughout this jelly-like structure no nervous system can be detected, but a contractile spot or vesicle is usually observed, and also a dark spot, termed a *nucleus*.

Stomatoda.—Included under this name are certain animals of low organization and simple structure; an advance, however, in complexity of arrangement, is observable.

As an example of the class we may take the Vorticella or bell-polyp, the name indicating the appearance of the animal, its form being that of a bell attached to a long stalk or stem; at the upper part of the bell or body is a mouth encircled by small hair-like processes, called *cilia*, which move rapidly, and create a constant current, drawing the prey of the animal within its reach. The mouth leads into a canal closed at the other end, and in the substance of the body is a contractile spot and dark nucleus.



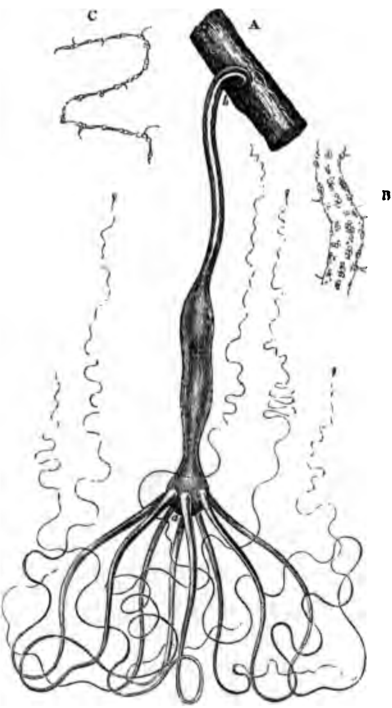
The Vorticella (in various states of fission, A, B, C, D, E, F).

An advance in organization is thus presented over the Amœba, as the Vorticella is provided with a proper digestive cavity, though the mouth serves both for the purpose of receiving food and ejecting the portions not digested. The functions and character of the

contractile vesicles and coloured nuclei already mentioned is quite uncertain, but they seem to be pretty generally present both in the Vorticellæ and Amœbæ.

The Cœlenterata.—We now come to a division of the animal kingdom remarkable for the free communication of the alimentary canal with the general cavity of the body; and of this type two classes may be given as the leading subdivisions: first, the Hydrozoa, and second, the Actinozoa.

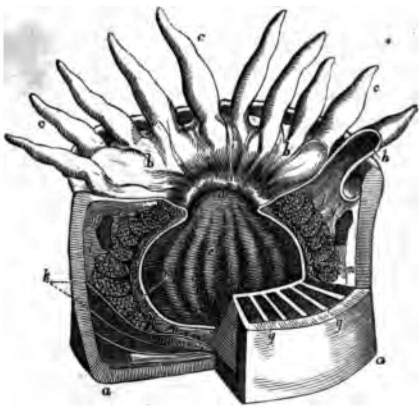
Hydrozoa.—In describing the Hydrozoa, it will be necessary to take an animal called the hydra as an example—a creature provided with a long, funnel-shaped body, having a mouth at one end, surrounded by arm-like projections, termed tentacles, and at the other a sucker, by which it attaches itself to surrounding objects. The body consists of two layers, between which are a num-



A Hydra: A, a piece of stick; B, C, portions of tentacula magnified; a, head; b, sucker.

ber of greenish cells, supposed to secrete some fluid that assists in the process of digestion. The mouth leads into a digestive cavity, which is closed at the other end, as in the Vorticella. One peculiar character deserves notice: if a Hydra is cut in pieces, each portion is capable of becoming a perfect Hydra.

Actinozoa.—Of this class the actinia is the type: an animal that has a round body, with short tentacles surrounding the top. In the centre is a mouth, leading into a sac-like stomach, between the coats of which and the wall of the animal's body is a considerable interval, subdivided by partitions; and at the bottom



The Actinia.

Sectional view: *a, a,* base; *d,* mouth; *c, c,* tentacula; *e,* stomach; *f, g, h, k, l, m,* cavity of body.

of the stomach is an opening, through which the fluid products of digestion pass into the general cavity of the body, to nourish the animal tissues. Here, again, we may stop to observe the advance in organization. The body of the animal just described is divided into

separate layers; a definite cavity for digestion exists, but no special arrangement for promoting the process, in the form of cells pouring forth solvent fluid. A considerable advance, therefore, has been made, as compared with the very simple structure and arrangement of the animals included in the Protozoa. As yet no special apparatus has appeared for conveying the nutritive fluid through the animal frame, nor has any trace of a nervous system been detected. The Actinia presents neither; but in the sub-kingdom next to be described, both these systems will begin to make their appearance.

MOLLUSCA.—In the lowest types of the Mollusca there is no very great advance in organization over the beings belonging to the sub-kingdom already described; in fact, till lately, some molluscs were classed with polyps, and not a few are propagated by the simple process of budding—a mode of reproduction greatly resembling the growth of a twig from the stem of a plant.

There is no special form to be traced in this sub-kingdom; but it is remarkable for the predominance of the visceral organs in proportion to the other parts of the body. In all molluscs the body is soft, and enclosed in an elastic skin, lined with muscular fibres, constituting what is called a *mantle*, by which (when one exists) the shell is secreted. In all the higher species there is a very considerable advance in complexity of structure; the alimentary canal is more perfect, and does not communicate with the general cavity of the body by any direct opening; at one extremity of the canal is the mouth, and at the other the anus or rent for excrement. The whole canal is divided into three portions: the first, leading from the mouth to the stomach, is termed the œsophagus; the second is the stomach itself; and the third, extending from the stomach to the anus, is the intestine. The products of digestion transude through the walls of the canal, and are distributed to the body by a series

of vessels forming a vascular system. The blood circulating in these vessels is white or bluish; and in the higher orders of Molluscs it is propelled through the body by means of a heart, containing two chambers, one called an auricle, and the other a ventricle. A respiratory apparatus, usually adapted for aquatic life, in the form of gills or branchiæ, is common; and lastly, a distinct nervous system, and organs of special sense, as those of vision and hearing, are developed. No special arrangement of the nervous centres obtains, but as a rule, there is about one nervous mass or ganglion for each important organ, one large ganglion commonly being situated on the œsophagus. Occasionally the mouth of molluscs is not situated on any prominent portion of the body, nor surrounded by any of the organs of special sense; the animal is then said to be *acephalous*, or headless; on the other hand, when the mouth is placed on a projecting part or head, the term *encephalous* is applied.

Amongst the most important classes in this sub-kingdom are the Bryozoa, Tunicata, Conchifera, Pteropoda, Gasteropoda, and Cephalopoda.

The *Bryozoa* comprises molluscs of the lowest type, creatures greatly resembling polyps, and formerly classed as such.

The *Tunicata* are sac-like animals, enclosed in a second sac, having no calcified shell, nor any distinct head; but they are provided with well-marked respiratory and digestive organs. Creatures included in this class are exclusively marine animals.

Conchifera, comprising two orders,* includes animals that are also acephalous, but possess a bivalved shell, to which they are attached by one or more muscles. Respiratory organs exist in the form of branchiæ; and two common shell-fish, the oyster and cockle, may serve as examples of the class.

Pteropoda.—Animals of this type are marine; some are provided with a shell and all have a distinct head, and possess peculiar organs of locomotion, in the

* Lamellibranchiata and Brachiopoda.

form of lateral fins. Sea-butterflies is a name applied to these animals, on account of their fin-like arms, and the rapid movements they make with them.

Gasteropoda.—Animals grouped under the name of Gasteropoda, have a foot-like process on the ventral surface, usually a conical, univalved shell, and respiratory organs adapted in some for breathing air, in others for living in water. Limpets and snails belong to this class.

Cephalopoda, or the cuttle-fish tribe, comprises animals furnished with either two or four gills, and certain appendages to the head serving as organs of locomotion. Some Cephalopods possess a shell, but others want this covering; as examples of the class, the cuttle-fish and nautilus may be taken.

In the Mollusca and following sub-kingdoms, a certain relation in the position of the vascular, nervous, and alimentary systems, can be traced; thus, in the Mollusca, the vascular, or *hæmal* centre, is on the dorsal surface of the animal, and the nervous or *neural* on the ventral, the alimentary canal being in the middle.

ARTICULATA, or, as it is sometimes called, the Annulosa, on account of the arrangement which pertains in this sub-kingdom, namely, that of the division of the body of animals included in it into segments. In the lowest forms of Articulata, however, this segmentation is not observed.

The position of the hæmal and neural system is like that of the Mollusca; the *hæmal* centre being situated on the dorsal, and the neural on the *ventral* surface of the body. Externally, there is a tegumentary or *dermo-skeleton*, sometimes soft, as in worms; sometimes hard, as in crabs and lobsters; but no internal skeleton is ever developed.

The muscles or motive organs are arranged internally, acting on the external parts, locomotion being

produced by a number of hairs attached to the body externally when feet are wanting.

A tolerably perfect vascular system is present in the higher forms of Articulata, circulation being carried on either by contraction of the blood-vessels themselves, as is the case in the leech; or by means of a distinct heart, as in insects.

The alimentary canal is divided in a manner similar to that of molluscs, and the nervous system consists of a number of ganglia, connected by nervous cords, a rudimentary brain appearing in the œsophageal ganglion, which is frequently larger than the rest. The organs of special sense are considerably developed, especially, for instance, the eyes of insects; and a respiratory apparatus in the form of gills, or, more commonly, as sacs communicating with the air, is present. The generative system in this sub-kingdom is highly developed, but reproduction sometimes takes place by gemmation or budding.

The principal divisions of the Articulata, are the Rotifera, Echinodermata, Annelida, Myriapoda, Crustacea, Insecta, and Arachnida.

Rotifera. A class remarkable for the low type of the animals it contains; amongst them may be mentioned the rotifer, which derives its name from a number of revolving wheels surrounding its mouth.

Echinodermata, contains beings termed encrinites resembling the hydra, but having a calcareous shell; another subdivision is the Asteriadæ, included under which is the star-fish, an animal having a calcareous shell and possessing what is termed a *water vascular system.*

Annelida comprises the various kinds of worms, which may be arranged according to their possession of branchiæ: the Abranchiata and Branchiata. To the former, the leech and earth-worm belong, and to the latter, the nereis and serpula.

The body of annelids is composed of a number of

segments or *somites*, usually provided with rows of hairs projecting laterally; the leech, however, has a smooth skin, and a body made up of about thirty somites, with a sucker at either end; its mouth is furnished with three jaws and sixty teeth, twenty in each jaw; the mouth leads to a complete alimentary canal, and, in addition, a vascular system is present, consisting of a dorsal and two lateral blood-vessels, conveying red blood. The nervous system comprises twenty-one pairs of ganglia, connected by nervous cords; and this arrangement of the nervous masses is common to the Annelida generally. Lastly, in the leech both sexes are united in one animal, such creatures being termed *hermaphrodites*.

Crustacea.—In this and the following classes, a true heart is found, and also true blood-vessels. The exterior of the body is protected by a hard articulated skeleton, such as is seen in crabs and lobsters; and all crustaceans are grouped according to the number of their segments, one order having fourteen or less, and another twenty-one segments.

Myriapoda is divided into two orders: Millepedes and Centipedes; the first containing animals allied to worms; the latter, creatures resembling insects. The breathing apparatus is now arranged along the sides of the body, a communication with the external air taking place by pores.

Insecta is a most varied class, the animals included under it possessing a highly developed organization.

Insects may be classed either according to the arrangement of their jaws, whether sucking or chewing; or according to the number and character of the wings they possess, as Aptera, (wingless), Diptera Neuroptera, &c. In insects a distinct marking exists between the body or thorax, and the head and abdomen, and the number of their legs is usually six.

Arachnida comprises such animals as the spider and scorpion, creatures greatly resembling insects, but provided with visual and respiratory organs

differing in construction. The number of their legs is usually eight, and there is also an apparatus for the formation of silk, enabling these creatures to spin a web.

VERTEBRATA.—Ranking far above all other divisions of the animal kingdom is the Vertebrata, with man, and animals most resembling him, at its head. In this sub-kingdom, the predominance of the nervous system, and the possession of an internal or endo-skeleton, afford marked characteristics; moreover in all vertebrate animals, the endo-skeleton, which is sometimes osseous, sometimes cartilaginous, consists of a spinal column formed of vertebræ and certain prolongations. Taking an imaginary vertebra as the type, it will be found to be composed of a central portion called the "body," or centrum, from which, passing backwards and forwards, are two arches, the neural and hæmal; the former, destined to protect the nervous, and the latter, the vas-

FIG. 1.

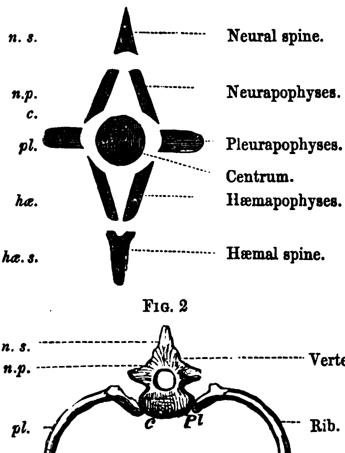


FIG. 2

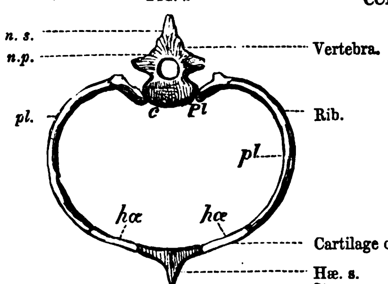


Fig. 1 represents a typical vertebra, and Fig. 2 the various parts as they are subsequently developed. Similar letters refer to similar parts in the two diagrams.

cular system. Added to these, are diverging appendages which assist in completing the structure of the bony frame; thus, from either side spring processes called pleurapophyses, which when completely developed, unite with the hæmapophyses or lateral portions of the hæmal arch, forming the ribs and enclosing the thorax. In this way the entire osseous frame is considered to be formed from a longitudinal series of vertebræ, each vertebra being composed of a body, arches, and appendages, which in different parts of the column may be very unequally developed; thus, it has just been shown how the ribs and bony walls of the chest are produced; and in the same way, the vertebræ at the upper extremity of the column are greatly expanded and modified, forming the skull; in like manner, the pelvis is developed at the lower end.

The nervous system in vertebrate animals is complex, consisting of numerous nerves, given off from the brain, spinal cord, and sympathetic ganglia.

The organs of digestion and circulation are entirely distinct, and a very perfect glandular system exists, comprising a pancreas, spleen, liver, and kidneys.

There is also a very complete respiratory apparatus, consisting of lungs, or some analogous arrangement.

The two sexes are never united in one animal, but are always distinct, and, with one exception,* every animal in the sub-kingdom has red blood.

Vertebrata are divided into four great classes, Fishes, Reptiles, Birds, and Mammals.

Fishes possess either osseous or cartilaginous bones, not differing much in arrangement from the typical method already described; the hæmal arches are far more developed than the neural, and the vertebræ of the spinal column are loosely connected, presenting large intervertebral spaces filled with gelatinous matter.

Fishes have no necks, and their anterior extremities

* The amphioxus.

or pectoral fins are attached just behind the head. No sternum or breast bone is found in animals of this class, but all are provided with a considerably developed dermal skeleton, consisting of fins and scales, the latter occasionally being osseous, as in the sturgeon. The brain in fishes is small, and the sensory part of the nervous system preponderates. The respiratory apparatus consists of gills adapted for exposing the blood circulating in them to the action of the air in the water, which, entering the mouth, passes out again through the gills. The digestive apparatus in some fishes permits the food to regurgitate and be triturated by teeth placed in the throat or pharynx, but if the œsophagus is long, as in the shark, this regurgitation does not takes place. A glandular system, consisting of a well-developed liver, is constantly found, and, in some instances, a spleen, and pancreas. Most osseous fishes are provided with a swim-bladder, which is a hollow bag containing air, and homologous to the lungs of other vertebrata; but its use in fishes is to assist them to rise or sink, by varying the quantity of air in the sac by compressing its walls.

The vascular system will be described in the chapter on circulation. The organs of special sense are not so highly developed as in the higher vertebrata, and, as a general rule, cartilaginous fishes are of a lower type than osseous.

Reptiles.—Animals included in this class are cold-blooded, and, for the most part, endowed with a low degree of vitality, being sluggish in their habits, frequently passing the winter months in a state of torpor. Many of these animals have a very flexible spinal column, composed of a large number of vertebræ, and some are provided with a prolonged breast bone or sternum, though in others it is wanting. Reptiles have a neck separating the head from the body; their circulation is single, and the nervous system, especially the brain, but little developed. The class may

be divided into four orders: Chelonia, Sauria, Ophidia, and Batrachia.

Chelonia—the turtle and tortoise tribe—includes animals provided with four feet, and a protection for the body formed by two bony plates, that on the back termed the carapace, that on the chest the plastron; the latter consisting of an excessive development of the sternum and ribs.

Sauria, or lizards, have either four or two feet, and a body covered with scales, the skin in some species possessing the peculiar power of changing colour when the animals are excited. The internal skeleton is provided with a long spinal column composed of many vertebræ, the greatest number being in the tail. The ribs, which are movable, commence in the neck and join a very prolonged sternum in front.

Ophidia, or serpents, possess an extremely elongated body, destitute of feet, but frequently covered with scales. The skeleton consists of a very long spinal column, connected with a great number of ribs but having no sternum. Serpents possess a peculiar power of opening their jaws to a great extent, and are often provided with poison bags or glands situated under the eye, the venomous fluid being poured out through an opening in one of the teeth.

Batrachia, or the frog tribe, comprises animals which, in their early stage of existence, respire by means of gills or branchiæ in addition to the lungs; but in their more advanced state of being the branchiæ are lost, and the lungs alone act in respiration—a metamorphosis seen in the change from the tadpole to the frog. Batrachia possess a skeleton with a shortened spine, without a tail, the ribs also being wanting; the skin is smooth, destitute both of scales or shell. The circulatory apparatus differs in the orders just enumerated, the animals contained being greatly affected by vicissitudes of temperature, and possessing but a low development of the organs of special sense.

Birds.—The class Aves comprises animals which, in

their plan of organization, present a marked similarity. The skeleton of birds consists of a spinal column with a variable number of vertebræ in the neck, and a short osseous tail sufficient only to support the tail feathers. The skull is a complete bony case, and the ribs are prevented from too free movement by spur-like processes called "diverging appendages." The sternum is always strongly developed, covering in the whole front of the chest and part of the abdomen, giving attachment to the under muscles of the wings. At the top of the chest are the two clavicles or collar bones, united into an arch called the "*furcula*," stretching out between the wings, keeping them more or less widely apart according to the power of flight. Wings are the upper extremities, or arms and hands of birds, developed and adapted for the purpose of locomotion through the air. The bones are hollow, containing air, giving lightness to the whole frame. As a general rule, the bodies of birds are covered with feathers destined to defend them from the rapid changes of temperature to which they are exposed. The feathers are excessively developed on the tail and wings, usually providing a broad expansion of surface to act on the air in flight. The beak varies in different tribes, being "hooked" in all birds of prey.

The vital endowment of birds is considerable as their activity is great. The vascular and nervous systems are much more elaborately developed than in reptiles. Respiration is carried on by means of lungs, the cavity of the chest communicating with the hollows in some of the bones of the wings. The digestive organs are peculiarly arranged, and will be afterwards noticed.

Mammals.—At the head of the animal kingdom is the class Mammalia, including man and animals whose organization is far more perfect than that of any other class. The name mammal is derived from two glands, or mammæ, situated on the breasts of both male and female, largely developed in the latter, enabling them

to suckle their young. Mammals have a spinal column composed of vertebræ, divided into various regions; the number of vertebræ in the cervical region or neck is almost universally *seven;* in the back or dorsal region it varies from *eleven* to *twenty-five;* in the loins and tail there is a considerable difference, the number in the tail varying from *four* to *forty-five.* The skull or cranium is always articulated to the spinal column by a kind of pivot; the upper jaw is fixed, the lower, formed of two portions, being movable. The teeth are very characteristic, varying according to the food on which the animal is destined to live. The chest, or thorax, is composed of ribs united to a sternum, varying in the extent of its development. Arms and legs always exist, except in the Cetacea or whale tribe, where the anterior extremities are merely fins, and feet entirely wanting. The blood of all mammals is warm, but as they are not so active in their habits as birds, their circulation is slower, and the requirements for nourishment less constant. The lungs are double, enclosed in the thorax, which is separated from the abdomen by a partition or diaphragm. The nervous system and organs of special sense are completely developed; the vascular system is double, consisting of a heart with four chambers, and two sets of vessels, called arteries and veins. The alimentary canal varies in its arrangement in different orders, but in all it is very complete, and more or less complex. Mammals may be divided into Placental and Implacental; or those in which the young are nourished and perfectly developed in the uterus of the parent, and those which bring forth their young in a state of incomplete development.

Implacental Mammals.—Under this sub-class two orders are grouped, the Monotremata and Marsupialia.

Monotremata.—As an example of the order, the ornithorhynchus may be cited, an animal found only in Australia, inhabiting marshy grounds and rivers.

In form it somewhat resembles a seal, with webbed feet to assist it in swimming, and a broad bill closely resembling that of a duck. The anatomical structure of the animal is very peculiar, the mammary glands being developed in a very rudimentary manner, but their presence is sufficient to determine the position of the creature in the animal scale.

Marsupialia, or pouched animals, as the opossum and kangaroo, bring forth their young before they are completely developed, or even capable of movement. Whilst in this condition, the young attach themselves to the numerous mammæ of the parent, being protected by a pouch of skin which extends over the abdomen of the mother. This pouch is supported by means of two peculiar bones springing from the pubis.

Placental Mammals.—Contained under this sub-class are the Cetacea, Pachydermata, Ruminantia, Edentata, Rodentia, Carnivora, Cheiroptera, Quadrumana, and Bimana.

Cetacea are animals resembling fish in their outward appearance, but possessing the characteristics of mammals; thus, they are provided with mammæ, respire by means of lungs, and have warm blood circulating in their bodies. As they breathe by means of lungs, they are frequently compelled to come to the surface of the water in which they live, to take in a fresh supply of air. The neck is very short, though it contains seven vertebræ; and the anterior extremities, in the form of fins, are alone present, attached close behind the head. Some Cetacea are herbivorous, as the Halicore dugong, siren, or sea cow, and often leave the water to seek food on land; others, as the whale, are provided with a peculiar apparatus for ejecting the water that enters the mouth at the time they seize their prey; the water passes through the nostrils into a sac, which is capable of being compressed by powerful muscles, and is thence violently expelled through a small aperture at the top of the head, the act being termed "blowing."

Pachydermata, or thick-skinned animals, such as the hippopotamus, elephant, and hog, are all more or less herbivorous. Some animals of this order have feet terminated by two or four toes, as in the wild boar and hippopotamus; whilst, in others, the feet end in a single toe, covered by a hoof, as in the horse and zebra. Lastly, the order contains animals called "proboscidians," provided with a snout or proboscis as the elephant.

Ruminantia includes the camel, deer, giraffe, &c., animals which have the power of masticating their food a second time, termed chewing the cud. Ruminating animals mostly possess horns springing from the head, and are provided with cloven feet.

Edentata are quadrupeds wanting front, cutting, or incisor teeth, their food being chiefly vegetable. Included in this order are the armadillo, sloth, anteater, &c.

Rodentia are animals provided with two large incisor teeth in the front of each jaw, and feed entirely on vegetables, as the squirrel, rat, hare, &c.

Carnivora possess both cutting and grinding teeth, their food being of a mixed kind. Carnivorous animals may be divided into *Aquatic*, or those that are amphibious, as seals; *Digitigrade*, or animals that walk on their toes, as the dog, hyæna, cat, &c.; *Plantigrade*, where the whole sole of the foot is placed on the ground in walking, as in bears, badgers, &c.; *Insectivora*, comprising animals like the mole and hedgehog, their principal food being insects, many of them leading subterraneous lives, and passing the winter in a state of torpor.

Cheiroptera are distinguished by the possession of a membrane extending from the neck to the end of the toes, enabling them to support themselves in the air. Like birds, they are provided with very strong clavicles to keep the upper extremities apart. Under the order Cheiroptera rank various kinds of bats.

Quadrumana comprises animals with four hands, as

monkeys, apes, &c.—creatures which greatly resemble man in their anatomical structure.

Bimana contains but one representative, namely, man.

Amongst mammalia, the order Bimana holds the highest rank, being represented by the various races of mankind; and though another order of mammals—Quadrumana—is classed according to the possession of a certain number of hands, still the character of the hand of man derives a special peculiarity from the very perfect opposing action the thumb has to the fingers; a characteristic which is only very slightly marked in the hands of other animals, as in monkeys. The length of the lower extremities in man, and the position of the foot at right angles to the leg is remarkable, and also the method of walking, by which the weight of the body can be borne on one leg at a time.

In man the erect posture and broad hips, together with the peculiar position of the face beneath the brain, so that its front and the forehead are in the same plane, contrasts in a marked manner with the posture, the narrow hips and projecting face of apes and monkeys, animals which, in many respects, anatomically resemble him. The size of a man's face also bears a small proportion to that of his whole head, and though the brain does not differ much in conformity from that of some animals, it is larger in proportion to the area of the body, and to the number of nerves given off from the spinal cord.

Temperature has a much less effect on man than on most animals. His food, too, is of a much more varied description, and his teeth are of a more uniform length.

Lastly, "he is endowed with reason, and possesses an immortal soul."

The characteristic of an endo-skeleton is common to vertebrata. An internal skeleton or framework of bones serves as a support for the soft parts, the

muscles being arranged with a view to their action on the various bones to which they are attached. The bones themselves are so arranged that they not only afford support and attachment for the muscles, but also serve to protect the more important organs, as the brain, lungs, heart, and great blood-vessels. In man, the osseous framework consists of a spinal column, from which spring a number of arched bones called ribs, enclosing a cavity—the chest or thorax. Surmounting the spine is the skull or cranium—a bony case for the preservation of the brain and organs of sense. At the lower extremity of the column is a broad expansion of bone called the pelvis, and articulating with this are the lower limbs, by means of the thigh-bone or femur. The upper limbs articulate with the scapulæ or shoulder-blades.

The spinal column in man is composed of twenty-four distinct rings of bone called vertebræ, held together by strong bands of ligaments, and by an elastic substance called the intervertebral substance, or cartilage. The column is not straight, but has a series of curves so arranged that any force applied shall be resolved, and not directly be transmitted to the head. The first seven vertebræ are termed cervical, and form the neck; the next twelve are the dorsal, and the remaining five lumbar. The size of the vertebræ becomes greater from above downwards; and at the lower extremity of the spine is an expansion of bone formed by amalgamated vertebræ, called the sacrum.

The spinal column affords protection to the spinal cord or marrow which runs down the centre, and also gives attachment to the ribs and muscles of the back, keeping the body erect by the manner in which it articulates with the pelvis, and that with the lower extremities.

The ribs, twelve in number on each side—seven true, and five false—form the chest, springing from the spine behind, and meeting in the front at the breast bone or sternum; the spaces between the ribs are occupied by

muscles (intercostals), and thus a cavity is formed which contains the heart and lungs. This cavity is shut off from the abdomen by a strong muscular partition called the diaphragm. Beneath the thorax is the abdominal cavity, extending from the diaphragm to the pelvis, and shut in all round by muscular walls, the abdominal muscles. In this cavity are situated, on the right, the liver; on the left, the spleen; in the centre, the stomach and pancreas; behind, on either side of the spine, one of the kidneys; and occupying the remaining space, the intestines. In the cavity of the pelvis is the bladder.

Thus it will be seen that the cavity of the chest is quite distinct from that of the abdomen; the vessels, nerves, &c., that pass from the chest into the abdomen, have, therefore, to perforate the diaphragm. There is no such division between the abdominal and pelvic cavities, which communicate altogether, and, in fact, form one great cavity.

THE ANIMAL KINGDOM.

PROTOZOA	Astomata. Stomatoda.
CŒLENTERATA	Hydrozoa. Actinozoa.
MOLLUSCA	Bryozoa. Tunicata. Conchifera. Pteropoda. Gasteropoda. Cephalopoda.
ARTICULATA	Rotifera. Echinodermata. Annelida. Crustacea. Myriapoda. Insecta. Arachnida.

- VERTEBRATA ...
  - Pisces.
  - Reptilia ...
    - Chelonia.
    - Sauria.
    - Ophidia.
    - Batrachia.
  - Aves.
  - Mammalia
    - Implacental...
      - Monotremata.
      - Marsupialia.
    - Placental......
      - Cetacea.
      - Pachydermata.
      - Ruminantia.
      - Edentata.
      - Rodentia.
      - Carnivora.
      - Cheiroptera.
      - Quadrumana.
      - Bimana.

N.B.—The above table shows only the divisions of the animal kingdom so far as the previous description has extended.

Summary.

The animal kingdom having thus been briefly sketched, rather with a view of showing the general plan of arrangement observed amongst organized beings, than of entering into any detailed account of particular animals included in the various classes, sub-classes, and orders, we may now proceed to consider more fully the anatomy and physiology of the human subject, examining all parts of the body with greater care, and referring also to their actions and functions, at the same time taking notice of the more marked variations in the lower animals.

But before commencing an anatomical description of the human frame, it will be necessary to dwell briefly on the principal chemical compounds entering into its organism, and the various tissues making up its structure.

OF THE CHEMICAL COMPOSITION OF THE HUMAN BODY.

The human body is composed of various organic and inorganic compounds, and these, together with the changes they undergo, will next be noticed. The principal *inorganic* compounds in the tissues are water and the salts of lime.

Water enters into the composition of the animal frame to so great an extent, that the weight of the body can be reduced two thirds by evaporation. But all the contained structures do not possess an equal amount; thus, the softer tissues contain a larger quantity of water than the harder; for example, brain substance contains 80, muscle about 70, and bone only 10 per cent.

The *use* of this fluid in the body is to render the various tissues supple, and to assist in the chemical changes that occur; it aids also in dissolving the food when introduced with it into the stomach, and enables the process of absorption to take place more readily.

The most important *salts* that exist in the body are phosphate and carbonate of lime.

Phosphate of Lime forms the great bulk of bones and teeth; in the former, as much as 40 to 60 per cent. is present, and in the enamel of the latter about 90 per cent. is found. This salt exists also in small quantities in cartilage and muscle, and constitutes the chief part of the shell of crustaceans.

Carbonate of Lime is likewise found in bones and teeth, and is the principal component of the shell of molluscs.

Chloride of Sodium enters into most tissues of the animal frame; albumen partly owes its solubility to its presence, and it is contained in muscle, cartilage, blood, &c.

Phosphate of Magnesia and *Fluoride of Calcium* are found in small quantities in bones; the fluoride has also been detected in the blood and milk.

Silica has been traced in the hair; but though it enters largely into vegetable tissue, it does not exist elsewhere in the body.

Iron, *Hydrochloric Acid*, and *Carbonate of Magnesia* are also found in some of the animal tissues and fluids.

All these inorganic compounds are taken into the body with the food and drink, and are acted upon afterwards either by contact with other salts or by the oxygen of the air, forming new affinities and combinations.

OF THE ORGANIC COMPOUNDS IN THE BODY.

THE organic compounds in the human frame may be divided into four classes: the Albuminous, Oleaginous, Gelatinous, and Saccharine.

ALBUMINOUS PRINCIPLES consist of Albumen, Fibrine, Caseine, and Globuline—all known as protein compounds, containing oxygen, hydrogen, nitrogen, and carbon, in nearly the same proportions. Certain characters are possessed by these compounds in common; thus, they are met with both in the solid and fluid form; they all contain sulphur, decompose readily, and are soluble in water, though not in alcohol.

Albumen may be regarded as the type of the entire class, and can be obtained nearly pure in the form of "white of egg;" it occurs very largely in the body, especially in the nutritive fluids, as the blood and lymph, and from it, in combination with fatty and mineral matter, the tissues are generated. Albumen coagulates by heat, and is precipitated by nitric and sulphuric acid.

Caseine constitutes the chief ingredient in the milk of mammals; it differs little from albumen in chemical composition, but does not coagulate easily by heat, and has a very different action with lactic and acetic acid. Caseine is not soluble in water, unless an alkaline or earthy base is present.

Fibrine may be ranked as "vital," for it shows a

tendency to pass into an organized state spontaneously. Muscle is principally composed of fibrine, and it exists in a fluid state in the blood, coagulating when that fluid is drawn from the body, or when the being in whose vessels it flows dies.

Globuline is one of the constituents of the blood corpuscles; its chemical composition resembles that of the substances already mentioned, and intimately united with it is a substance called *hæmatine*, which is supposed to contain iron, and to assist in colouring the blood corpuscles.

Gelatinous Compounds.—When the bones, tendons, and skin of animals are boiled, a semi-solid substance is yielded, which on cooling becomes hard and brittle; this substance is termed gelatine, of which two forms exist, glutine or gelatine proper, and chondrine.

Glutine is derived from bone and white fibrous tissue, and gelatinizes so strongly, that one part in a hundred forms a jelly. Tannic acid precipitates it, and it is readily affected by decomposition.

Chondrine resembles glutine in its general properties, but is obtained only from cartilage. Both glutine and chondrine contain oxygen, hydrogen, nitrogen, and carbon, very nearly in the same proportions.

Oleaginous Principles.—Fatty matter is non-azotized, that is, contains no nitrogen. The fatty substances which present themselves in the greatest abundance in the human body are margarine and oleine; but in other animals the former is commonly replaced by stearine.

Margarine is a white substance, found chiefly in human fat, but existing in small quantities, in combination with stearine, in the fat of the lower animals. margarine melts at 118° Fahr.

Stearine much resembles the preceding, and melts at 114° Fahr.

Oleine exists only in small quantities in fat, but forms the principal part of fixed oils. Stearine and margarine are both dissolved in it at the ordinary

temperature of the body. The saponification of the three substances just mentioned gives rise to acids with similar names. If the fat of animals is saponified, glycerine is produced—a faintly yellowish fluid, with a sweetish taste, which may be regarded as the base of all the fatty acids. It contains carbon, oxygen, and hydrogen; its solvent power is little inferior to that of water, and as an article of diet it is very nutritious. Oleaginous matter is found in adipose tissue, also in blood and chyle, its chief use being to aid in maintaining the animal heat.

SACCHARINE COMPOUNDS assist in the calorifying process. Sugar is found in the blood and chyle, where its presence seems to depend on the existence of starch, or sugar itself, in the food. In certain diseases, the urine is found to contain saccharine matter, and it has lately been discovered that the liver has the power of generating sugar.

Glucose or grape sugar, such as is found in blood, differs considerably from common cane sugar, being much less sweet, and only half as soluble, and also less disposed to crystallize.

Glucose or grape sugar .... $C_{12}H_{14}O_{14}$.
Cane sugar .... $C_{12}H_{11}O_{11}$.

Lactic acid is closely related to sugar, and has been detected in the blood; it is, moreover, a constituent of the gastric juice, besides existing, occasionally, in the urine, sweat, and possibly in the bile.

TABLE SHOWING THE CHEMICAL COMPOUNDS ENTERING INTO THE FORMATION OF THE TISSUES OF THE HUMAN FRAME.

Inorganic Compounds in the Body.

Water.
Phosphate of lime.
Carbonate of lime.
Chloride of sodium.
Phosphate of magnesia.
Fluoride of calcium.
Silica.
Iron.

Hydrochloric acid.
Carbonate of magnesia.
Sulphur, phosphorus, potash, and soda.

Organic Compounds in the Body.

Azotized, or Nitrogenous compounds.	Albuminous compounds	Albumen, casein, fibrin, globulin—O,H,N,C.
	Gelatinous compounds	Glutin and chondrin, containing O,H,N,C.
Non-azotized, or Non-nitrogenous compounds.	Oleaginous compounds	Margarine, stearine, and oleine, containing O,H,C.
	Saccharine compounds	Glucose and lactic acid, containing O,H,C.

Excrementitious Substances are those that pass out of the system after having been eliminated by the excretory organs of the body. Of these, two groups may be formed, one possessing nitrogen, and the other carbo-hydrogen in excess, constituting the chief components of the urinary and biliary excretions.

The most important excrementitious substance is *urea* $C_2H_4N_2O_2$, found in the urine, blood, and the various fluids separated from the blood. It forms colourless crystals, readily soluble in water, having a saltish taste, easily uniting with many salts, and is excreted in large quantities from the body.

Lithic or Uric Acid exists in the urine, usually combined with ammonia. The quantity of this acid is rather less than one in a thousand parts in human urine, its place being supplied by hippuric acid in the urine of herbivorous animals. The chemical composition of lithic acid is $C_{10}H_4N_4O_6$.

Analysis of Urine.

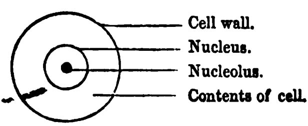
Water	950·0
Urea	13·2
Uric acid	·8
Salts of soda, Potash and ammonia, with extractive matter.	36·0
	1000·0

The specific gravity of healthy urine in the human subject is from 1015 to 1025, water being taken as 1000; and the quantity passed during the day, is in summer, about 30, and in winter, about 40 ounces; the quantity of urea contained in the urine passed in twenty-four hours amounting to nearly 400 grains.

OF CELLS AND CELL LIFE.

THE forces that exercise their influence in the living body, are either physical or vital; the former, regulated by laws already known to us, the latter exhibiting phenomena which cannot be accounted for by physical science, and found only in living beings, manifest alone through the medium of organized structure. In the vegetable kingdom, and in some of the lowest forms of animals, the whole fabric is composed of *cells*, but in the higher scale of beings, *fibres* and *membranes* are added.

A cell, whether animal or vegetable, is a vesicle or shut sac of membrane, filled with some kind of matter, containing a granular body, called the *nucleus*, which either floats in the cavity or is attached to the wall of the cell.



Simple cell.

The form of cells is various; if in a free state, usually spheroidal, but when in close contact they frequently become polygonal. They also exist as flattened discs—the blood corpuscles for example—or fusiform in shape, as in muscular fibre. Their diameter varies from the $\frac{1}{300}$th to the $\frac{1}{15000}$th of an inch.

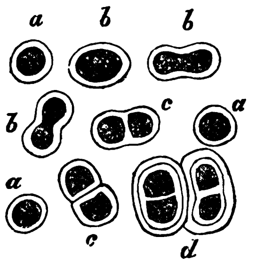
Structure of cells.—The cell wall appears to be a delicate, structureless membrane, holding together the

contents of the cell, but permitting the transudation of fluids by endosmotic action.

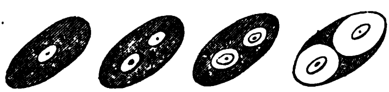
The contents of cells are very various, being either fluid or solid, and the ingredients contained, as milk, bile, &c., give different endowments to the parts where the cells are found.

Nuclei of cells are granular in structure, commonly of a round form, about $\frac{1}{6000}$th of an inch in diameter, and occasionally presenting a distinct central body or corpuscle, called the *nucleolus*. Every cell has a separate existence, and is developed either from an original blastema, or by subdivision of a previously existing cell.

The multiplication of cells by division gives rise to 2, 4, 8, 16, 32, &c., new cells. At the commencement of the process, a slight elongation of the cell takes place, owing to a tendency in the contents to separate into two halves; the cell wall gradually folds in, till at length the division is complete, and two fresh cells are formed. Very frequently, fission takes place in the nucleus, drawing the cell contents into two parts, and the wall either folds in as just stated, or a new wall forms round each part of the nucleus, producing two new cells in the parent cell, and distending it till the original cell wall cannot be distinguished. Where more rapid growth takes place, the nucleus divides



Formation of two new cells by the division of the original cell: *a*, *a*. cells before division; *b*, *b*, and *c*, various stages of the process; *d*, formation of four cells by repetition of the same process.


Multiplication of a cell by division of the nucleus.

into several portions, and numerous cells are generated in the old cell. On the other hand, where development takes place from *blastema*, minute molecules first appear to aggregate, and form a little rounded mass or nucleus, from which the cell originates, the wall rising, as it were, from the nucleus.

Lastly, cells may be formed from single particles in blastema, without the existence of any nucleus. Cells, therefore, originate in a fluid substance called "a blastema," or germ fluid; and the changes that take place in the chemical composition of the cell contents, the subdivision into new cells, and the alteration in form, are the chief manifestations of cell life. When cells become matured, they die, by gradually dissolving; or the cell wall bursts, and forms a "secretion," by permitting the contents of the cell to escape.

Fibres.—Some physiologists contend that fibres are made up of cells which have undergone elongation or fusion; others, that they may be generated by a process called "fibrillation,' in the original blastema.

OF THE PRIMARY TISSUES OF THE HUMAN BODY.

When cells become aggregated, and fibres blended or interlaced, structures are formed, from which the various tissues are produced, and the different textures existing in the body held together. Elasticity, combined with a certain degree of firmness, is required in these connective tissues; at the same time it is necessary that free movement should not be hindered, though the parts that they serve to unite must be held in sufficiently close contact to prevent any permanent displacement.

Areolar, or *Cellular Tissue* is that texture which is

found in the greatest abundance throughout the body; it serves to hold other textures together, enveloping the blood-vessels, nerves, and lymphatics, entering into the composition of muscle, and filling up spaces between different organs.

In structure, this important tissue consists of a number of delicate filaments arranged in a net-work, the interstices forming cells containing a very thin albuminous fluid resembling the serum of the blood diluted. Areolar tissue is very elastic, and has a vascular supply; but no nerves have been traced in it, except those that pass through, *en route* to other organs. The fibrous portion of this tissue consists of a mixture of two others, called white and yellow fibrous tissue.

White Fibrous Tissue is formed of wavy inelastic fibres, of a white colour, having a tendency to tear lengthways. The size of the fibres is not determined, but distinct fibres of about the $\frac{1}{20,000}$th of an inch in diameter have been observed. This structure is penetrable by few vessels, or nerves, and seems to have but a small amount of vital endowment, yet, when injured by accident or disease, is very rapidly repaired. Gelatine is nearly the sole component of the tissue, which forms almost the whole bulk of the tendons, ligaments, and fibrous membranes. The chief mechanical property of the texture is to resist tension without yielding.

Yellow Fibrous or Elastic Tissue consists of cylindrical fibres of a yellow colour, about $\frac{1}{7000}$th of an inch in diameter, having a tendency to curl up when broken abruptly. A very small quantity of gelatine enters into the tissue, which is found chiefly in the coats of arteries and the ligaments of the larynx. Elastic tissue derives its name from the possession of the property of great elasticity combined with that of resistance.

Synovial Membrane is found surrounding joints, being composed chiefly of the areolar tissue, covered

on the inner surface with a layer of cells. This membrane is very perfectly supplied with blood, and secretes freely a fluid called synovia, which lubricates the opposing surfaces of articulations.

Serous Membrane in structure greatly resembles the synovial, but it invests the cavities in the body, and is not connected with the joints; it secretes a fluid sufficient only in quantity to moisten the surface of the tissue. Both the textures just described possess a considerable degree of strength and elasticity.

Mucous Membrane differs materially from those already noticed, exceeding them in thickness and complexity of structure. It consists of three layers; an epithelial, a proper mucous, and a fibrous layer. The epithelial covering presents itself under three different forms; the most common variety is the *tesselated*, composed of flat, oval, nucleated cells, arranged in one or more layers, constituting a form of epithelium found on the membrane lining the mouth, throat, and œsophagus; the second variety is termed *cylindrical* or *columnar*, being composed of nucleated cells of a conical or pyramidal form, arranged closely together, in contact with the mucous membrane by one extremity, and free at the other, forming a variety of epithelium that exists on the lining membrane of the stomach and intestines; the third kind is called *ciliated*, and presents cells resembling those found in the columnar epithelium, but provided with numerous fine hair-like processes springing from the free extremity of the cells, constituting a form of epithelium that covers the mucous lining of the respiratory tracts. Glands, called *villi* and *follicles*, frequently stud mucous membrane; there is also a very free vascular supply to the structure, giving it a deep red colour, and a viscid, mucous secretion exudes abundantly from its surface; moreover, it forms the lining of the air-tubes, the throat, œsophagus, stomach, and intestines, joining the skin at the orifices of the body, as the mouth and nose. The composition of the secretion;

and the use of the membrane varies in its different situations; thus, in the stomach and intestines, the function of the membrane is to secrete a solvent fluid to act on the food, and enable absorption to take place, but in the air-tubes it aids in the process of respiration, and pours out a totally different secretion.

Adipose Tissue is composed of a number of small vesicles containing oleaginous matter, termed fat-cells, held together by areolar tissue. For the most part, the shape of the cells is spheroidal, but the quantity of areolar tissue mixed with them is variable; thus, the adipose tissue forming the marrow of bones contains very little, and sometimes it is altogether wanting, a delicate plexus of blood-vessels holding the cells together instead.

No nerves or lymphatics have been traced to this tissue, but they pass through it to other parts. Adipose tissue exists in large quantities in the human body, being next in abundance to the areolar, the amount being increased by oleaginous food, heat, and rest, but in some persons and in certain diseases there is a tendency to the development of fat, though the food may be deficient and great exertion taken. Fatty tissue aids in facilitating movement, and forms a sort of cushion for certain organs, as is the case with the eyeball in the orbit; it also assists in maintaining the animal heat, by furnishing a reservoir of combustible matter, without which a continued supply of food would be necessary, and the privation of aliments for a few hours might be fatal. Animals, especially of the herbivorous kind, feed and fatten in the summer months, thus laying up a store of nourishment in their bodies for the winter. Death from starvation takes place more slowly in fat than in lean animals, the time being proportional to the quantity of adipose tissue contained in the body. When the absorption of fatty tissue has taken place to any considerable extent, that peculiar sunken appearance of the cheeks and eyes is observed, which so often ac-

companies exhaustive diseases or want of proper nourishment.

Cartilage is a white elastic substance, somewhat analogous to bone, existing under two forms, the "temporary" and "permanent;" the former, found at birth, afterwards becoming ossified, gradually disappears; the latter, met with in the adult, chiefly in the joints covering the ends of the bones, aids in reducing friction. In youth cartilage is of a pearly whiteness, and very elastic, but it becomes yellow and has a tendency to ossify in old age.

The structure of this tissue is apparently homogeneous, but if carefully examined, is seen to be fibrous in texture. It originates, however, in cells, which are more or less abundantly mingled with the fibres; though, in some cartilages, as those between the vertebræ, the structure is destitute of cells or cartilage corpuscles, being entirely fibrous.

Articular Cartilage, or that present in the joints, is so closely united to the bones, that it can scarcely be separated from them, and has its free surface covered with synovial membrane. Neither nerves nor blood-vessels have been proved to penetrate the tissue, which is supposed to be nourished by imbibition through the walls of surrounding vessels. It is, however, stated by some writers that vessels too minute to admit the red corpuscles of the blood penetrate all cartilaginous structures.

The chemical composition of cartilage generally, is albumen, water, and a small quantity of phosphate of lime. A peculiar substance called *chondrine*, somewhat resembling gelatine, is obtained from cellular cartilage.

Summary of the Primary Tissues of the Human Body.

1. *Simple Fibrous Tissue*, including the white and yellow varieties, and entering into the composition of areolar tissue, tendons, ligaments, and aponeuroses.

2. *Cellular Tissues*, including adipose tissue and cartilage.
3. *Tubular Tissues*, as blood-vessels, &c.
4. *Sclerous Tissues*, comprising bones, teeth, &c.
5. *Fibro-cellular Tissues*, including the various forms of mucous and serous membranes.
6. *Muscular Tissues*, comprising all the varieties of muscular structures found in the body.
7. *Nervous Tissues* embracing the whole mass of the nervous system, including the brain, ganglia, and nerves.

BONE.

THE bones in the human body are variously grouped, into long, flat, and irregular; the femur and humerus are examples of the first, the ribs of the second, and the vertebræ of the third kind.

When a bone is viewed with the naked eye, it presents a somewhat laminated structure in the long bones, the laminæ being arranged in a concentric manner round a central cavity or *medullary canal.* At the extremities of the bone the structure is more spongy in texture, termed cancellated, and a number of hollows, called *cancelli*, are found communicating with the medullary canal. The surface of bone is covered with a membrane—the *periosteum*—rich with blood-vessels, affording nourishment, and aiding in repairing injuries to the osseous substance. In the medullary cavity, a peculiar soft substance—the medulla—is found, with a lining membrane of delicate blood-vessels. Bone-substance is traversed by canals, communicating freely with each other, forming a kind of network; into these canals, which are termed the *Haversian canals*, the lining membrane of the medullary canal enters. The diameter of one of these canals is from $\frac{1}{200}$th to the $\frac{1}{500}$th of an inch; their use is,

to convey the small blood-vessels throughout the substance of the bone.

A *vertical* section of a long bone will show the Haversian canals communicating, as in Fig. *a*.

If a *transverse* section (Fig. *b*) be made, the ends or orifices of the Haversian canals will

FIG. *a*.

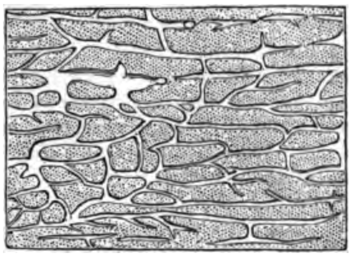


FIG. *b*.

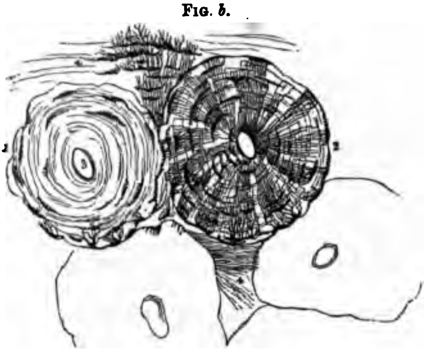


Fig. *a*, Longitudinal section of a bone. Fig. *b*, Transverse section of a bone.

appear, surrounded by concentric rings of bony matter, studded with dark spots, which, when more closely examined, prove to be cavities. These are termed *lacunæ*, lenticular or oval in form (with their longer sides turned towards the Haversian canals), in diameter about $\frac{1}{2400}$th of an inch; and proceeding from them run minute canals, called the *canaliculi*, too minute, indeed, to admit of conveying blood-vessels, their largest diameter being only $\frac{1}{20,000}$th or $\frac{1}{14,000}$th of an inch, so that the blood corpuscles could not enter them; yet it must be sup-

posed that they draw some kind of nourishment from the surrounding vessels. Bone substance, therefore, is permeable to blood-vessels in all directions. At the extremities of a bone where a joint occurs, the periosteum is wanting, and cartilage exists. The medullary membrane acts as an internal periosteum; but the medulla does not seem to be required for actual nourishment of bone tissue, as in birds air takes its place. Nerves doubtless exist, though they cannot be traced in bones.

Composition of Bone.

If bone is exposed to the action of fire, some of its ingredients are consumed, and a white, friable earth is left behind. Again, if it is submitted to the action of dilute nitric or muriatic acid, it becomes soft, resembling cartilage. In the first place, the gelatinous portion was removed by the agency of heat, and the earthy parts left; in the second, the earthy particles were dissolved out, and the animal parts remained untouched. The earth of bone is principally phosphate of lime; it also contains carbonate of lime and other salts. Roughly, the composition of bone is as follows:

Organic matter	Cartilage and vessels	33·0
Inorganic matter	Phosphate of lime	52·0
	Carbonate of lime	10·0
	Chloride of sodium	0·25
	Other salts, as phosphate of magnesia and oxides of iron,	4·25
		100·0

According to Dr. Stark and Dr. Carpenter, the hardness of bone does not depend on the amount of earthy matter contained, nor does the flexibility or transparency indicate a want of earthy material: "For the transparent, readily cut bones of fish, contain the

same amount of earthy ingredients, in proportion to their gelatinous basis, as the dense, ivory-like leg-bones of the deer and sheep;" and, according to the same authority, the stability of osseous tissue most probably depends on the quantity of water entering into its composition. Respecting varieties depending on age, it appears that the bones of old people contain more earthy matter than those of young ones, the want of earthy particles producing the disease called rickets in children.

Development of Bone.

In the early periods of life bones are not hard and firm, but soft and yielding, cartilage being the substance of which they are composed. The development of bone is accomplished in two different manners: either there is a cartilaginous mould or matrix first formed, which subsequently becomes ossified by the deposit of bony matter in its substance, or a membrane exists in which ossific matter is developed. In the first instance, then, a kind of mould is formed for the after deposit of bone by cartilage, which does not materially differ from permanent cartilage, such as covers the ends of bones in articulation. Canals form in this structure, and the cartilage-cells arrange themselves in rows longitudinally respecting the axis of the bone; between the cells is an intercellular substance, and in this bony matter is first deposited from the blood. In a long bone, ossification springs usually from two or three starting-points at once, there being "a centre of ossification" for the shaft, and one for each extremity. As the development advances, the various canals are gradually formed traversing the structure. When bone is developed in membrane, as is the case with the cranial bones, fibres and cells are first observed in the membrane; the fibres harden by the deposit of earthy matter, and an irregular network is thus produced, which becomes closer and harder as

the process advances, laying the foundation for the new bone.

BONES IN OTHER ANIMALS.

Fishes.—In some fishes (the cartilaginous) the bones contain but little earthy matter, though in other species (the osseous fishes) harder bones exist; but in no case is there a medullary canal, or any approach to laminated structure.

Amphibia.—The bones in this type have no laminæ, nor, except in the case of the crocodile, any medullary canal. The chemical composition of the osseous matter resembles that of fishes.

Birds have firm but elastic bones, with a somewhat laminated arrangement of structure, and large internal canal, which contains air instead of marrow.

Mammalia.—In the cetacea or whale tribe, the bones are fibrous externally, but in quadrupeds they resemble generally those of man, only coarser in texture.

THE TEETH.

Before passing to a description of the soft parts, the teeth may be described. Man is provided with two successive sets, the *first, deciduous* or *milk* teeth; the *second* or *permanent*, which replace the first. The former are twenty in number, and the latter thirty-two.

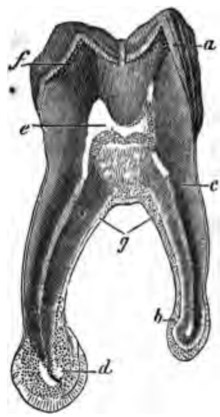
Permanent Teeth.

	In each jaw.	
Incisors	4	... 2 central and 2 lateral.
Canine..............	2	... 1 on each side.
Bicuspid	4	... 2 on each side.
Molars..............	6	... 3 on each side.
	16	

The milk teeth are differently divided, as there are no bicuspids, and only four molars in each jaw.

A tooth is divided into a crown, the part above the gum, a neck or constricted part round the base of the crown, and a root or fang which fixes the tooth into the socket. The teeth are composed of three distinct structures, ivory, enamel, and cortical substance, or cement.

The ivory or "tooth bone" forms the principal part of the tooth, and consists of very minute, tapering, and branching fibres, embedded in a denser interfibrous substance. Above, the ivory is covered in by the enamel; below by the cement.



Section of a tooth.
a, enamel; *b*, *g*, *d*, cementum; *f*, *c*, ivory; *e*, cavity; *a*, the crown; *b*, *d*, the fangs.

The *enamel* forms a crust over the exposed part of the tooth or crown, being thickest at the upper part. It is composed of minute hexagonal crystalline fibres, resting by one end against the surface of the ivory.

The *cement* covers the root or fang; it resembles bone in structure, and possesses a complex arrangement of cells and tubuli.

In the centre of the tooth is a cavity containing a pulp and a nerve. The pulp consists of a mass of soft vascular matter, and the nerve is a branch from the "dental." The teeth are adapted to the food and habits of the animals to which they belong; those that live entirely on vegetables are provided with grinding teeth, but carnivorous animals possess only cutting teeth. Man is furnished with both varieties, as his food is of a mixed character.

Teeth in other Animals.

Fishes are frequently provided with teeth, sometimes in great numbers, and occasionally moveable. The composition of their teeth is a modification of dentine, and they are usually found on the bones forming the anterior apertures of the mouth, but more rarely at the posterior part, or in the pharynx, and, more rarely still, on the roof of the mouth, in the median line.

Reptiles are in many cases edentulous, or toothless, as in the toad; but in others, as the tortoise and turtle, there exists a horny sheathing to the jaws. Where teeth are present, they are fewer in number than in fishes, and are composed of hard, unvascular, dentine.

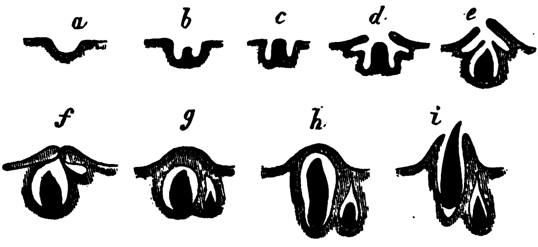
In crocodiles the teeth are of a conical form, and composed of a series of hollow cones, one within the other, so that when the outer tooth wears away, a new one is ready to supply its place. The interior of the tooth is never filled up, and at all periods of the animal's life fresh germs will be found in the interior of the tooth, or its socket ready to occupy the place of the old and worn casing.

Mammals.—The teeth of the mammals do not vary much in composition, though in form and number great differences exist. Animals that are destined to live on flesh, are provided with cutting teeth; herbivorous animals possess gnawing and grinding teeth, and those whose food is of a mixed character have teeth of both varieties.

In the whale, the place of teeth is supplied by plates of thin flexible substance, called "whalebone," which consists of a kind of fibrous horn, fringed at the edges, serving to retain the small animals on which the cetacea feed. The "whalebone" is connected with the bones of the upper jaw only, the lower being destitute of any such appendage. In the teeth of many

mammals, the arrangement of the enamel is peculiar; thus, in animals that constantly grind their food, and wear down the surfaces of the teeth, the enamel, instead of merely coating the surface, is arranged in deep vertical layers, alternating with bony matter, as in the horse and elephant—an arrangement that secures, in all states of the teeth, a rough, hard, grinding surface. Again, in animals like the hare, or common rabbit, where the incisor teeth are in constant use, a provision is made for their continual renewal, and the enamel is so distributed, that being very much thicker in front, the hinder part wears away quicker, and a sharp cutting edge is always preserved.

DEVELOPMENT.—In the human embryo the teeth are developed from small papillæ arising in a groove that forms in the upper jaw between the lip and palate. The first appearance of this furrow, which is called the primitive dental groove, occurs at the sixth



a, b, c, d, e, showing the formation of the dental groove, papillæ, and opercular flaps; *f, g, h, i,* showing the subsequent development of the teeth and the formation of a cavity of reserve, with second teeth.

week of fœtal life, and in about another week a small ovoid papilla of granular structure makes its appearance in the floor of the groove. Several of these papillæ arise in succession, constituting the rudiments of the various milk teeth. About the tenth week, small processes spring from the sides of the dental

groove, and, extending gradually, enclose the papillæ in a sac or follicle. At the thirteenth week the whole of the rudimentary papillæ are enclosed in follicles, and the form of the papillæ begins to alter, assuming the shape of the future tooth; the papillæ grow more rapidly than the follicles, till at length they protrude from the mouth of the latter, and at the same time flaps or opercula are developed at the mouths of the follicles, which extend over and enclose the growing tooth. Above these again the edges of the dental groove unite and cover in the whole.

As soon as the follicles are thus closed in, the teeth gradually enlarge, become calcified, and at length make their way up through the gum.

The periods at which the eruption of the milk teeth occurs are as follows:

Central incisors,	at the 7th month.	
Lateral incisors,	„	7th to 10th month.
Anterior molars,	„	12th to 14th „
Canine,	„	14th to 20th „
Posterior molars,	„	18th to 36th „

The development of the permanent teeth which succeed to the milk teeth in after-life is provided for by the formation of a small chamber in the gum, called a cavity of reserve; and after the deciduous teeth have begun to form, the permanent are slowly developed, till at length the latter press on and cause the absorption of the under part of the former, and, pushing them out from the gum, take their place.

The periods at which the eruption of the permanent teeth occurs are:

First molars,	at the $6\frac{1}{2}$ year.	
Two middle incisors,	„	7th „
Two lateral incisors,	„	8th „
First bicuspid,	„	9th „
Second bicuspid,	„	10th „
Canines,	„	11th to 12th year.
Second molars,	„	12th to 13th „
Wisdom teeth,	„	17th to 21st „

JOINTS.

A JOINT or articulation may be movable or not; but comparatively few bones are so firmly attached to those next them as not to permit of more or less movement.

A movable joint has its opposing surfaces expanded, and coated with an elastic substance called cartilage; a membrane surrounds it on all sides, forming a closed sac, and a fluid termed *synovia*, secreted from this membrane (which is called the synovial membrane), lubricates the surfaces of the joint. Lastly, it is retained in position by short, strong, bands of glistening fibres or ligaments, and by the tendons of various muscles.

Joints may be divided into three classes—Synarthrosis, Amphiarthrosis, and Diarthrosis.

SYNARTHROSIS, where an articulation exists between bones without movement being permitted, as between the bones of the skull, or the teeth in their sockets.

AMPHIARTHROSIS, where the joint has motion intermediate between the Synarthrosis and Diarthrosis, as between the vertebræ.

DIARTHROSIS, where free movement is permitted as in the shoulder, hip, &c. All these classes admit of further subdivision, but it will only be necessary to mention the Diarthrodial class, which may be divided into Arthrodia, Ginglymus, and Enarthrodia.

Arthrodia, where the motion is slight, as between the bones composing the foot.

Ginglymus, a term applied to joints where the movement resembles that of a hinge, as in the knee and elbow.

Enarthrosis, where the most perfect freedom of motion is found, produced by an arrangement of parts called a ball-and-socket joint. The round extremity of a bone, the femur, for example, is in such a joint, received into a cup-like cavity, coated with cartilage, and held in place by a strong round ligament, passing from the head of the bone to the bottom of the cavity, the whole being surrounded by a bag of ligamentous membrane called the capsular ligament, and strengthened by the tendons and muscles around the joint. The hip and shoulder are the two examples in the body of the true form of this articulation.

Articulations.

Synarthrosis	Sutura	A form of union exemplified in the junction of the bones of the skull.
	Harmonia	A mode of union such as is observed between the two halves of the upper jaw.
	Schindylesis	A form of junction exemplified in the union of two cranial bones, called the vomer and rostrum.
	Gomphosis	The mode of union between the teeth and their sockets.
Amphiarthrosis		A form of articulation observed between the bodies of the vertebræ.
Diarthrosis	Arthrodia	A form of joint existing between the bones of the wrist and ankle.
	Ginglymus	A joint like a hinge, such as the elbow, knee, wrist, and ankle.
	Enarthrosis	The true ball and socket joint, as the hip and shoulder.

MUSCLES.

THE framework of bones, with its various joints, having been briefly sketched, the covering of muscles, which constitutes the great bulk of the animal body, bestowing on it form and symmetry, must next be noticed.

Muscles, commonly called "the flesh," are of a red colour and of different forms, the shape varying greatly, according to their position and the uses for which they are destined in the body; some are long, narrow, and rounded, stretching out between two distant points of bone attached at either end, as in the muscles moving the fingers and toes; others are broad and flat, enclosing cavities, such as the muscles that constitute the abdominal walls.

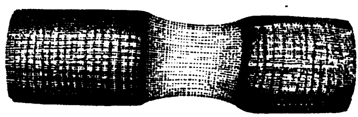
With regard to their functions, muscles may be grouped into two sets, voluntary and involuntary, the former being chiefly connected with movements effected through the agency of the spinal nerves, obeying the influence of the will; the latter, very slightly or not at all controlled by the will, but acted on by stimuli applied to themselves, and connected more with the vegetative functions; for example, the muscles that move the limbs are voluntary, and act under the direction of the mind, but the heart which is a hollow muscle, acts independently of the will, and is excited by a stimulating influence, contained (according to some writers) in the blood which passes through it, but more probably by an influence residing in the structure of the organ itself.

Structure of Muscle.

If examined with a magnifying glass, a muscle will be found to be made up of *fibres*, arranged parallel to each other, and bound together in *fasciculi* or bundles by a delicate web of areolar tissue. If the fibres that

form these fasciculi are examined under a higher power, each one will be seen to be itself composed of bundles of still more delicate fibres, and in voluntary muscle these primitive fibres will exhibit transverse markings or *striæ*, but in the involuntary they will appear plain or unstriped.

In *striated* or *voluntary* muscular structure, two sets of markings may be observed, one transverse, and the other longitudinal; and the primitive fibres may be again separated into *fibrillæ*, which present a beaded appearance, and, as far as our observation goes, constitute the ultimate structure of the muscular fibre. These elements of the primitive fibres are bound up together in a delicate sheath called the *sarcolemma*, the existence of which may be demonstrated when the fibre ruptures, and contracts in the interior, leaving the sarcolemma still entire between the separated ends. The shape of muscular fibre is somewhat polygonal, varying in diameter in different animals; thus, in man the fibres vary in diameter from the $\frac{1}{400}$th to the $\frac{1}{350}$th of an inch; in women from the $\frac{1}{450}$th to the $\frac{1}{400}$; in fish, the $\frac{1}{220}$th; in insects the $\frac{1}{420}$th; in reptiles, the $\frac{1}{480}$th, and birds the $\frac{1}{860}$th.



A fibre broken across, showing the untorn sarcolemma.

Unstriped muscular fibre, such as is found in the involuntary muscles, ordinarily presents itself in flattened bands of from $\frac{1}{2000}$th to $\frac{1}{3000}$th of an inch in diameter, collected into bundles and interlaced, forming the variety of muscular structure which invests cavities, as the alimentary canal and bladder.

The muscular structure of the *heart*, which is made up of *striated* muscular fibre, is peculiar, in presenting "the general arrangement of *non-striated* muscle, as far as regards the form and interlacement of the fasciculi;" but the bands present striated markings,

and also contain, scattered in them, elongated fusiform-shaped cells, with a central, staff-shaped nucleus.

Vessels and Nerves in contact with Muscular Structure.

The substance of muscle is perforated in every direction by minute blood-vessels termed *capillaries*, and it is probable that each fibre is in contact with a separate capillary; for though these blood-vessels do not penetrate the fibres themselves, nourishment is imbibed through the sarcolemma.

Striated muscles are, of all tissues, except the skin, the most freely supplied with nerves; the sarcolemma, however, is not pierced by these nerves, which are in contact only with, and act through it; nor can the termination of the nerve fibres be there found, for when a branch is given off from a trunk, it forms a loop, and returns either to the same or an adjacent trunk.

Non-striated muscles are very deficient in the supply of nerves, and those that *are* found chiefly come from the sympathetic system. The heart in this respect, also, though a striped muscle, resembles the unstriped variety.

Development and composition of Muscular Fibre.

Striated muscular fibre is developed in a soft blastema from nuclei, which arrange themselves in lines. From the nuclei, cells become developed, at first in contact by their adjacent walls, which at length disappear, the continuous chain of cells forming a tubular membrane—the sarcolemma. The nuclei, however, still remain, and, in addition, numerous fine granular particles begin to appear; and an arrangement of the nuclei and granular matter into lines now takes place, forming the transverse striæ and making up the fibrillæ, till at length, fresh matter being deposited in

the interior of the sheath of sarcolemma, the contained muscular fibre becomes completely developed. Muscle contains about 23 per cent. of solid matter, and three of salts, the elements entering into the composition of the tissue being carbon, oxygen, hydrogen, and nitrogen.

Analysis of Muscle.

Proper muscular structure, with gelatine and albumen,	20
Phosphate of lime and salts	3
Water and loss	77
	100

Contraction of Muscles.

The power of contraction is one of the most important properties with which muscle is endowed, and may be excited by various means; thus, it may be produced by the actual contact of a body (especially of a pointed body) with muscular tissue, and it may also be called into activity by galvanic agency, or chemical influence. In this way the muscles of a limb just severed from the body may be thrown into contraction by touching their exposed surfaces with the point of a sharp knife, or by passing a galvanic current through their substance. When a fibre commences to contract, the change usually begins at the ends, a dark spot first appearing, which, spreading, gradually involves the whole diameter. The striæ are seen drawn more closely together, and the whole fibre becomes shorter and thicker. The increased thickness, however, is not commensurate with the diminished length, so that the muscles become firmer, and occupy less space after than before contraction. During the change, the sarcolemma does not contract in like manner, but rises in folds on the exterior of the fibres.

Muscular *irritability*, or, in other words, the power

of contraction, does not cease immediately after death, but is retained by different muscles in different degrees. The right auricle of the heart may possess contractility sixteen or seventeen hours after death, but the intestinal canal not more than an hour. This property of contraction arises from what is called the irritability of muscle; but there is another and different kind of contracton, which arises from what is called *tonicity*, and is affected, perhaps, by heat and cold. At a variable period after death—from seven to thirty-six hours, a stiffening of the muscles of the body takes place, called the "rigor mortis:" it is the last manifestation of tonic contraction. It commences and remains no fixed time after death, and has in some cases been so powerful that a corpse has been raised into a sitting posture.

Muscular contraction is followed by a period of relaxation; and if the contractions are repeated very frequently, a long period of rest is required before they can, to any extent, be renewed. Violent and frequent exercise increases the size of muscles, by stimulating an increased flow of blood to the part, producing an increased nutrition. The greater the size of the muscle, the more powerful will be its action; and the well-developed muscles in the arms of a blacksmith are usually cited as an example of the fact that exercise augments the size of muscles, and that increased power is consequent on the increased size.

As before stated, a muscle requires rest after contraction; but, on the other hand, the want of use or inactivity of muscular structure, produces wasting and consequent loss of power. An illustration of this result is afforded in cases of paralysis, where atrophy of the part affected generally takes place.

TENDONS.

Tendons are interposed between muscles and the bones on which they act, often enabling a muscle to act at a considerable distance from its attachment and position. Tendons, therefore, are attached at one end to muscles, at the other to bones; they are generally cord-like in form, expanded at the extremity which is in contact with bone, and intimately blended with the muscular structure at the other. Frequently the tendons are retained in their places, or in grooves in which they work, by sheaths and ligamentous bands. The chief constituent of tendon is white fibrous tissue, the fibres being arranged in parallel bundles, destitute of nerves, and but sparingly supplied with blood-vessels.

THE SKIN.

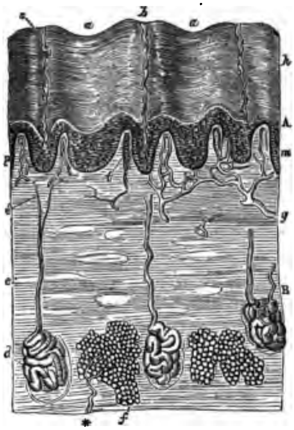
EXTERNALLY covering the framework of bones, muscles, and tendons, is the skin.

It is composed of three layers: first, the *cutis vera*, or *corium;* second, the *basement membrane*; and third, the *epidermis*, or *cuticle;* this last being the most external.

The *epidermis*, or cuticle, is the superficial part of the skin; it is level on its outer surface, but pitted on the under for the reception of the papillæ; it consists of a number of hard and horny flattened scales, like cells, which are continually dropping off from the surface or desquamating, whilst new ones are constantly being formed below. The deeper layer of the epidermis is termed the *rete mucosum* or *basement membrane*, containing the pigment cells that give the colour to the cutaneous structure.

The *cutis vera*, or *corium*, is the deeper portion of the skin, consisting of complex fibrous tissue, blood-

vessels, nerves, and lymphatics. The surface next the epidermis is elevated in many parts into ridges or *papillæ*, which receive by the touch impressions through the medium of the nerves distributed in their strucure.



A perpendicular section of the Skin: A, epidermis; *h*, its superficial layer; *m*, its deeper layer, the rete-mucosum; B, cutis-vera; *p*, *t*, papillæ; *d*, sudoriparous gland with its duct running up towards the surface cut across in one part (*é*), but continued on and opening at *s*; *b*, another duct from sudoriparous gland; *a*, *a*, surface of epidermis; *g*, blood-vessels; *f*, fat-granules.

Generally, papillæ are conical projections, consisting of delicate filaments of nerve fibres and ramifications of cutaneous blood-vessels and lymphatics. The size of the papillæ is variable; they are usually about $\frac{1}{33}$rd to $\frac{1}{22}$nd of a line in length, but rather larger in the skin of the sole of the foot and palm of the hand; and separating them into ridges are furrows into which the sweat glands open.

The surface of the corium presents also numerous depressions, the *sebaceous follicles*, lined with scales, continuous with the epidermis, through which they are open on the surface of the body; their function is to secrete an oily matter to defend the skin, by keeping it moist, and enabling it to resist the action of the air and heat.

The corium is highly vascular and looser in texture than the cuticle, being gradually united by its internal or deeper surface with the fat and cellular tissue of the body.

The *sweat* or *sudoriferous glands* are long convoluted tubes, seldom single, commencing in a sac-like manner in the fat beneath the skin, running up

through it in a tortuous way, and opening obliquely on the external surface of the epidermis in such a manner that the superficial scales of the cuticle lap over the mouth of the duct, forming a kind of valve. The function of the sweat glands is connected with the removal of superabundant moisture from the body, and has but little to do with the skin itself.

Use and Functions of the Skin.

The skin covers in the various textures of the body, and presents an extremely elastic and resistant surface to external influences, affording protection to parts exposed to pressure, as the heel and soles of the feet, by an increased thickness of the epidermis, and also receiving tactile impressions by aid of the papillæ, with which the entire extent of cutaneous structure is studded.

The skin exhales a certain quantity of moisture secreted by the sweat glands, sufficient to amount to about four pounds in twenty-four hours; there is always a constant exhalation going on, which is termed the insensible perspiration; but, when violent exercise is taken, this is increased and poured forth in the form of sweat. Heat and cold, the vascular and nervous systems, influence to a great extent the amount of this secretion; and as the kidneys ~~act by~~ draining the superfluous moisture from the body, the action of the skin has a certain relation to that of the kidneys; thus, when more urine passes, there will be less sweat exhaled, and when the action of the renal organs is checked there will be an increased flow of sweat from the skin.

In frogs and many inferior animals, it has been proved that the quantity of carbonic acid given off by their skin nearly equals that from their lungs; but, in man, where the lungs are so greatly developed, a much less quantity is evolved. The function of the skin, then, is clearly of vital importance; and, indeed, the fact may be readily proved; for when its action

is either totally or partially checked, as by varnishing an animal's body, or by the destruction of a considerable extent of cutaneous surface by heat, death takes place very rapidly; the system being unable to get rid of the required amount of fluid by exhalation from the skin, congestion of the internal membranes occurs, followed by an effusion of fluid into the cavities of the body.

Sweat has a specific gravity of 1004, and consists chiefly of water impregnated with chloride of sodium, phosphate of soda and lime, with lactic acid.

HAIR.

On the external surface of the body of most of the higher animals, either covering it entirely, or confined to certain parts, are horny filaments, termed hairs; in the human being these hairs are long and strong on the scalp; but covering every part even of the face, are other hairs, very minute and delicate.

a, b, c, d, Section of the root of a hair; *f, g, h, i, k,* follicle containing the root; *l, m,* papillæ.

Each hair has a *root* under the skin and a *stem*, which passes up through the cutaneous structure, and appears on its surface; the root or bulb is contained in a follicle, resting on a papilla, which is received into the lower part of the bulb, and to which the blood-vessels that nourish the hair can be traced. In

chemical composition hair resembles the epidermis of the skin, and contains an oily colouring matter. The use is to afford warmth and protection.

NAILS.

Besides the hair, the skin has other horny appendages, the nails, which may be considered to be an altered form of the epidermis. A nail has a root and body; the root is soft and thin, composed of cells, and received into a fold of the cutis, where a new production of nail substance is continually taking place; the body is the principal part of the nail, and is attached to the skin by its under surface, except at the end or free extremity. No blood-vessels or nerves have been traced in nails, and their composition is chiefly albuminous, with a little phosphate of lime.

GLANDS.

Glands are organs found in various parts of the body, destined to separate from the blood peculiar substances, which differ according to the gland pouring forth the secretion.

In structure, glands are *sacs* or *tubes*, formed of thin membranes lined with secreting cells, arranged in various ways, richly supplied with blood-vessels, and provided with an excretory duct. The most simple form of the organ is a pouch or sac open at one end, as in the follicles of the skin, or two or more sacs may unite, and open by a common duct, as in the glands of the eyelids. An advance on this arrangement exists where several pouches are bound up to-

gether into a lobe or cluster. If the sac is elongated into a tube, twisted, or convoluted, and bound up into masses by areolar tissue, a gland of complex structure is formed. The walls of these tubes or sacs are similar to mucous membrane, surrounded with an elastic coat, and richly supplied with blood-vessels, spread over them in the form of a network, but nowhere communicating directly with the interior of the sac or tube, the secretion exuding through the walls into the gland cells. The principal glands in the body are the liver, kidneys, pancreas, mammæ, and salivary glands.

OF THE ALIMENTARY CANAL.

Communicating with the skin at the orifices of the body, as the mouth and nose, is the mucous membrane, which is continued down through the whole alimentary canal, lining it in the entire extent.

The alimentary canal is a musculo-membranous tube, extending from the mouth to the anus, dilated specially in one part—the stomach. It is variously named in different parts of its course—mouth, pharynx, œsophagus, stomach, and intestines.

The Mouth is an irregular cavity, containing the instruments of mastication and organs of taste. Behind it is bounded by the soft palate; in front by the lips and teeth; on either side by the internal surfaces of the cheeks; above by the hard palate; and below by the tongue, assisted by the mucous membrane, stretched out in the arch of the lower jaw. The soft palate is situated at the back of the mouth, continuous above with the hard palate, and formed by muscles covered with mucous membrane. Suspended in the middle is a small rounded process called the uvula,

and passing outwards on either side is a curved fold or arch, forming the pillars of the palate. An anterior and posterior pillar exists on each side, united above, but separated below, having the tonsils lodged between them.

The *Tonsils* are two almond-shaped glands, situated between the anterior and posterior pillars of the soft palate.

The *Salivary Glands* are three in number on each side, named the *parotid*, *submaxillary*, and *sublingual*, all of them being provided with ducts opening into the mouth. The structure of these glands is termed *conglomerate*, the lobules of which they are composed being formed of convoluted tubes, bound up together into clusters by areolar tissue.

The *Parotid Gland*, the largest of the three, is situated just in front of the ear, extending for a short distance over the cheek, and dipping deeply behind the jaw. The duct from the gland traverses the muscles of the cheek, and opens into the mouth opposite the second molar tooth. Passing through the gland is the external carotid artery, and a large nerve —the facial.

The *Submaxillary Gland*, the next in size, is situated under the lower jaw, its duct opening below the tongue, near the frænum.

The *Sublingual Gland* lies along under the tongue, opening into the floor of the mouth by seven or eight small ducts.

The *Pharynx* or throat is a musculo-membranous sac, situated between the mouth and the stomach, reaching in extent from the base of the skull to the fifth vertebra of the neck. It is composed of three muscles on each side, termed *constrictors*, covered internally with mucous membrane, continuous with that of the mouth.

Besides the mouth and the œsophagus, the windpipe opens into the pharynx; and two apertures at the back of the nose, called the *posterior nares*, also lead into

the cavity, so that an elastic tube pushed up the nostrils would pass into the throat. In addition to these

1. The tongue.
2. The œsophagus.
3. The larynx or windpipe.
4. The epiglottis.
5. Cavity of the nose.
6. The pharynx.

openings, two small tubes, called *Eustachian tubes*, communicating with the internal part of the ear, also lead into the pharynx.

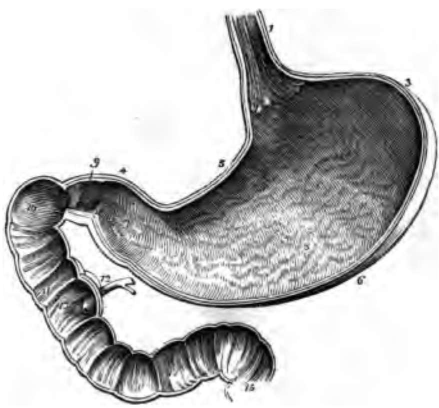
The *Œsophagus*, or gullet, is situated between the throat and the stomach, passing down behind, and rather to the left of the windpipe or trachæa, and also behind the arch of the aorta, and, continuing downwards, perforates the diaphragm and opens into the stomach.

The canal is larger at the upper portion, and presents the form of a tube, flattened rather than round,

composed of muscular fibres, arranged in two layers, the outer being disposed in a longitudinal, and the inner in a circular manner.

The mucous membrane lining the œsophagus is continuous with that of the throat, but is thicker in texture, and covered with a more distinct epithelium of the tesselated form; and from the mouth to the stomach, the whole extent of lining membrane is studded with numerous small glands, for the purpose of lubricating the surface.

THE STOMACH is a conical musculo-membranous bag, with two openings, one leading into the œsophagus, the other into the intestines. The position of this viscus is below the diaphragm, lying across the



Sectional view of Stomach.—1, the œsophagus; 2, cardiac orifice; 3, greater end; 4, lesser end; 5 and 6, greater and lesser curves; 9, pylorus; 10, 11, duodenum; 12, 13, bile and pancreatic ducts entering together; 14, 15, intestine.

abdominal cavity, the end into which the gullet leads *being towards* the left, and called the *cardiac* ex-

tremity, and that with which the intestines communicate being to the right, and termed the *pyloric* end.

The upper border of the *stomach* receives the name of the "smaller curve," and the lower border the "greater curve." The lining membrane of the abdominal cavity, the peritoneum, holds the organ in its place, and entirely covers its external surface.

The *walls* of the stomach are composed, proceeding from without inwards, of a muscular, submucous, and mucous coat.

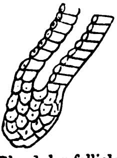
The *muscular* coat consists of three layers of fibres, arranged in a longitudinal, oblique, and circular manner.

The *submucous* coat is of a fibrous nature, composed of areolar tissue, strengthening the gastric walls, and containing the ramifications of the vessels and nerves distributed to the viscus.

Lastly, the *mucous* coat or lining structure of the stomach is a thick, soft, red membrane, which, when closely examined, is found to be marked all over with hexagonal depressions; and if a section is made through the membrane, perpendicular to its surface, it is found to be composed of a number of tubes closed at the end which rests on the submucous coat, and opening at the other into the bottom of the depressions already noticed.


Mucous membrane of the Stomach.

These tubes or *glandular* follicles, as they are called, are richly supplied with blood-vessels, and secrete the gastric fluid. The upper part of the follicles is lined with columnar epithelium; but the bottom and lower portion is made up and filled by nucleated cells, through the agency of which the gastric juice is secreted, and poured from the tubes into the cavity of the stomach.


Glandular follicle of the Stomach.

The INTESTINAL CANAL is a tube about thirty feet in length, leading from the stomach to the anus, varying in diameter in its different parts.

The chief division of the canal is, into *large* and *small* intestines, the small being about twenty-four feet in length, and the large only six.

The *small intestines* commence at the pyloric orifice of the stomach, and are divided into three portions, termed the duodenum, jejunum, and ileum.

The *duodenum* is about ten inches long, with the ducts from the pancreas and gall-bladder opening into it.

The *jejunum* and *ileum* together measure about twenty feet, but have no distinct separation.

At the end of the ileum, the *intestinal* canal suddenly becomes larger in calibre, and forms the large intestines.

The *large intestines* are also divided into three portions, called the cæcum, colon, and rectum; the last-named portion terminating the canal at the anus, which is guarded by a circular band of fibres, termed a sphincter muscle.

The mode of communication between the large and small intestines is peculiar, and is accomplished by the end of the ileum, being, as it were, thrust into the sac-like termination, or rather commencement of the cæcum, forming thereby a valve, called the ileo-cæcal valve. The whole canal, except the rectum, which is straight, lies convoluted in the *abdominal* cavity, being covered and held in position by the peritoneum.

The intestinal tube is composed, proceeding from without inwards, of a muscular, sub-mucous, and mucous coat. The muscular coat consists of two layers of fibres, one arranged in a circular, and the other, in a longitudinal manner; the sub-mucous coat has the same use and relative position as that of the stomach, but the mucous coat, though resembling that of the organ just mentioned as to the general structture, presents some marked differences.

In the whole length of the intestinal canal, simple follicles, called the crypts of Lieberkühn, are found; moreover, in the *small intestines*, the mucous membrane rises into folds called *valvulæ conniventes*, and a number of projections termed *villi*, composed of a plexus of arteries, a vein and lacteals, stud their entire surface. Small rounded, white eminences, called the *solitary glands*, are also scattered along this portion of the canal; but in certain parts of the whole tube special glands are found; thus, in the duodenum chiefly, are met with, small bodies, composed of minute lobules opening into ducts, resembling the salivary glands, termed the *glands of Brunner;* and in the ileum are found the *glands of Peyer*, forming oval patches, consisting of an aggregation of the solitary glands before mentioned. In the *large intestines*, the mucous membrane does not rise into folds, and no villi are discovered, but *follicles* resembling the crypts of Lieberkühn are scattered throughout the whole extent. All the glands and follicles mentioned as studding the intestinal mucous membrane have special functions to perform in aiding digestion, absorption, and excretion.

Summary.

The Alimentary Canal, therefore, comprises six divisions:

1. The mouth.
2. The pharynx.
3. The œsophagus.
4. The stomach.
5. The small intestines.
6. The large intestines.

Of *the Small Intestines* there are *three* divisions:

1. The duodenum.
2. The jejunum.
3. The ileum.

Of *the Large Intestines* there are also *three* divisions:

1. The cæcum.
2. The colon.
3. The rectum.

Of *the Glands of the Small Intestines.*

In the small intestines there are—

1. Villi.
2. Valvulæ conniventes.
3. Glands of Peyer.
4. Glands of Lieberkühn.

And in the duodenum the glands of Brunner in addition.

Of *the Glands of the Large Intestines.*

In all the large intestines there are—

1. Follicles (resembling the crypts of Lieberkühn).
2. Solitary glands.

THE STOMACH IN OTHER ANIMALS.—In the lowest forms of animals no difference between the stomach and other parts of the alimentary canal is observed, but in the Articulata and Mollusca the organ is distinctly developed. Many animals are provided with a reducing apparatus, to assist digestion by crushing the food before it enters the stomach.

BIRDS have a complex alimentary canal, with three dilated portions, the crop, proventriculus, and gizzard. The *crop* exists mostly in granivorous birds, being an enlargement of the œsophagus, into which the food is received and retained for some time previous to its passage into the stomach. A copious secretion, which aids digestion, is poured out by the crop from a glandular arrangement in its walls. The *proventriculus* and *gizzard* together may be considered to constitute *the stomach*, the former corresponding to the cardiac,

and the latter to the pyloric portions of the organ in mammals. From the walls of the proventriculus the true gastric fluid exudes, whilst the gizzard is a sac, composed of very strong muscular walls, for the purpose of grinding the food, the reduction being often aided by the presence of numerous small stones which birds usually swallow. This arrangement is curious, as the food is mixed with the gastric fluid before it is properly triturated by the gizzard. The deficiency of teeth in birds is supplied by this peculiar structure of the digestive organ.

In MAMMALS the reducing apparatus, consisting of variously formed teeth, is confined to the mouth; still, in some classes, the arrangement of the stomach seems to be subservient to the further reduction of the food before it is subject to the digestive process.

Ruminantia possess a gastric organ of complex arrangement, the stomach being divided into four chambers. The first is called the *paunch;* the second the *reticulum*, or "honeycomb-stomach;" the third is termed the *omasum*, or "many plies;" and the fourth and last stomach receives the name of the *reed*. The first two divisions, the *paunch* and *reticulum*, are rather dilatations of the œsophagus than parts of the stomach itself. The *paunch* is the largest cavity, and is destined to receive the food in a crude state, which remains some time in the cavity, being moistened by a secretion poured out from the glands in its walls; thus, the *paunch*, being a temporary receptacle for the food, is analogous to the crop of birds.

The *reticulum*, or second stomach, is termed "honeycombed," from the reticular appearance and irregular folding of the lining membrane. Between these folds are situated numerous water-cells, surrounded by muscular fasciculi. It is to this peculiar arrangement that the camel owes the power of existing so long without any fresh supply of water.

The cells can be closed or opened by the contraction

of the surrounding muscular fasciculi, so that when a supply of water is taken into the stomach it can be retained in the water-cells and poured out again, as required. Though all Ruminantia possess this power of abstaining from water, it exists only in a less degree in many of the animals in the class.

The *omasum*, or third stomach, is usually called "many plies," from the peculiar disposition of the lining membrane, which is arranged in folds, like the leaves of a book, the free edges being turned towards the centre of the cavity which leads into the fourth stomach.

The *reed*, or fourth stomach, is that in which the true gastric juice is poured out, and leads to the pylorus and intestines.

The manner in which the œsophageal tube passes into the stomach is remarkable; it is continued on through the first and second stomachs by a canal, called the *demi-canal*, with a longitudinal opening, bounded by two lips or bands of muscular fibre, so arranged that by the contraction of the muscular structure the opening into the first and second stomach is shut off and the canal closed, which then leads directly through into the third stomach. This must be kept in mind to understand the process of *rumination*. When food is first taken into the mouth and swallowed by a ruminating animal, it is very little masticated, and passes down into the first and second stomach in almost a dry state; after the food has become properly saturated with the fluids of these cavities, it breaks up into little balls, which return to the mouth to undergo complete mastication and become mixed with the saliva. These little pellets of food are formed by the compression exerted by the muscular fibres at the entrance of the œsophagus. After this second mastication the food is reduced to a semi-pulpy state, and passes again down the œsophagus, but being now soft and moist, instead of dry and hard, as it was when swallowed the first

time, it does not force apart the lips of the canal by which the œsophagus is continued through the first and second stomach; so that, instead of passing into these chambers, it is directed along into the third stomach, and from thence into the fourth, where it is acted on by the gastric fluid. Thus it appears that, in

Stomach of a Sheep: *a*, œsophagus; *b*, first stomach; *c*, second stomach; *d*, third stomach; *e*, fourth stomach; *f*, intestine.

the first instance, the food being swallowed without being chewed, forms a hard mass, which causes the lips of the slit in the *demi-canal* to open, and give entrance to the paunch and reticulum; but when the food has been reduced to a pulpy state by mastication, it passes along the canal without opening the lips, and enters the omasum at once.

OF THE LACTEAL AND LYMPHATIC SYSTEMS OF THE HUMAN BODY.

Lymphatics are very delicate tubes, provided with valves, somewhat resembling veins, forming a complete system of vessels existing in almost every part of the body, and connected with numerous glands, called lymphatic glands, which exercise a certain influence over the fluid or *lymph* conveyed by the vessels.

The lymphatics, after collecting into larger trunks, pour their contents into a sort of pouch, termed the *receptaculum chyli*, situated on the spine in the ab-

dominal cavity. From this pouch a duct, called the *thoracic duct*, leads up through the thorax, and opens into the left *subclavian vein* at the root of the neck, pouring its contents into the current of the blood.

LACTEALS are other vessels originating in the intestinal villi, which have already been described as "conical projections formed by a vascular network, containing in the interior vessels termed lacteals." The fluid product of digestion, called *chyle*, transudes into these lacteal vessels, and is carried by them into the thoracic duct, so that both chyle and lymph are poured into the same receptacle, and thence conveyed to the left subclavian vein, where the mixed fluid is poured into the blood.

OF THE TWO LARGE GLANDS SITUATED IN THE ABDOMINAL CAVITY—THE PANCREAS AND LIVER.

The Pancreas.

THE pancreas, or sweet-bread, is a long, hammer-shaped gland, situated behind the stomach, provided with a short duct leading into the duodenum. The structure of the gland is conglomerate, resembling the salivary apparatus, pouring forth a secretion very like saliva.

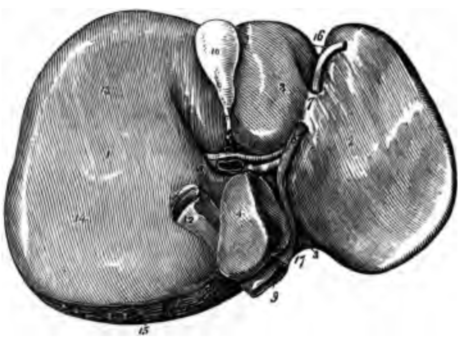
The Liver.

The liver is an elongated, conglomerate gland, composed of lobes, divided by fissures. The situation of the organ is on the right of the abdominal cavity, close under the diaphragm, being retained in position by prolongations of the peritoneum, called the *ligaments of the liver*.

On the under surface of the right lobe is a small,

pear-shaped sac, called the *gall-bladder*, invested internally with a lining membrane, arranged in a valvular manner. Leading from this sac is a duct, termed the *cystic duct*, a short tube, about an inch and a half long, with a diameter nearly equal to that of a crow-quill. Joining this duct is another small tube, coming from the substance of the liver itself, called the *hepatic duct*, the junction of the two forming the *common* bile-duct, or *ductus communis choledochus*, which opens into the duodenum, first passing for some distance obliquely through and between the walls of that intestine.

Running up through and behind the gland, partly embraced by its lobes, is the *vena cava inferior*, or large venous trunk that conveys the blood from the lower parts of the body to the heart; and as this



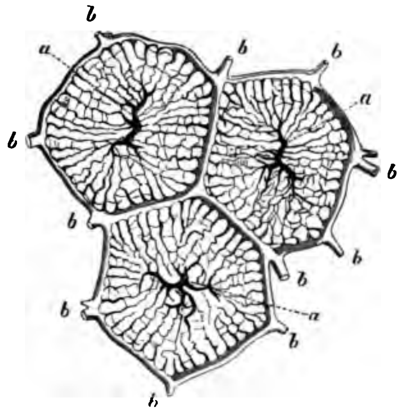
View of the under surface of the Liver: 1, 2, 3, 4, 5, lobes of the liver; 6, 8, 11, fissures of the liver; 9, 12, vena cava; 10, the gall-bladder; 13, 14, depressions on the under surface; 16, anterior border; 15, 17, posterior border.

vein passes through the fissure in which it is lodged the *hepatic veins*, coming from the substance of the liver itself, open into it.

The vessels ramifying in the substance of the liver consist of two veins, an artery, and a duct; thus, besides the branches of the hepatic veins, there are others *from the vena porta* (which is formed by the

union of venous trunks that return the blood from the intestines, spleen, and stomach) together with the *hepatic ducts* and *artery*, distributed throughout the substance of the gland. The structure of the organ is very complex, being made up of small *lobules*, composed of minute granular cells, termed

FIG. 1.



Horizontal section of Lobules of the Liver: *a, a, a, intra*-lobular veins; *b, b, b, inter*lobular veins.

acini, and held together by a fibrous covering, called Glisson's capsule. *Between* the *lobules* are spaces, called the *interlobular canals*, in which the subdivisions of the *portal vein* ramify, accompanied by the minute branches of the hepatic duct and artery.

FIG. 2.

Lobules of the Liver forming leaf-like projections on the Hepatic Vein: *a*, trunk of the vein; *b, b, b*, lobules.

If the lobules are cut through vertically, they present a foliated appearance, arising from the distribution of the *hepatic veins* in the centre. Thus, it appears that *in the substance* of the lobules the *terminal branches* of the *hepatic* veins ramify, receiving on

that account the name of *intralobular* veins, whilst the branches of the *vena porta* ramify in the canals *between* the lobules, and are, therefore, called *interlobular* veins. These two sets of veins communicate by minute branches passing off from the interlobular veins and entering the substance of the lobules, where they meet the intralobular veins, and form the *intralobular venous* plexus (see fig. 1). The other two vessels, the hepatic ducts and artery, which run in the *interlobular canals*, are distributed in the following manner.

The *hepatic artery*, derived from one of the large branches of the abdominal aorta, divides, on entering the liver, into very minute branches, which ramify in Glisson's capsule, on the walls of the hepatic duct, and in the substance of the lobules themselves, the terminal branches probably joining the *portal vein*.

The *hepatic duct*, as it enters the gland, bifurcates into two branches, and then divides into numerous smaller vessels, which ramify in the interlobular canals, and send off minute branches into the interior of the lobules, forming a *lobular biliary plexus*. The termination of the ducts, however, has not been discovered; probably they end in loops, or possibly they terminate by closed extremities.

The *function* of the liver is twofold—it separates from the blood a fluid called *bile*, which aids in the digestive process, and also produces certain changes in the blood submitted to its influence.

Blood is brought to the liver by the vena porta, and having circulated through the intralobular plexuses, passes into the hepatic veins, and is carried by them into the vena cava, where it is mixed with the blood coming from the lower parts of the body, and conveyed upwards to the heart.

As before stated, the liver exercises a certain influence on the blood passing through it; the hepatic veins, therefore, will contain blood of a different quality to that found in the portal vessels; thus, in

the hepatic, the blood contains less water, albumen, and salts, than in the portal, but a peculiar sugar, called *liver* sugar, similar to grape sugar, exists in the blood flowing in the hepatic vessels.

THE LIVER IN THE LOWER ANIMALS.

In the lower forms of animals the hepatic organ is of a very rudimentary character, but in Mollusca it is a large, well-marked viscus; it is, however, in Vertebrata that the structure becomes close and complex.

In *Insects* the structure of the liver is very simple, consisting of a number of distinct, filiform tubes, surrounding the alimentary canal, frequently opening into its cavity by several distinct apertures. The number and length of these tubes varies considerably; sometimes they are much longer than the alimentary canal, being convoluted or twisted; and their number varies from four to ten, or more. Their walls are lined with nucleated cells, which form a kind of epithelial covering, and pour out the biliary secretion.

In *Molluscs* the arrangement of the gland is still simple, consisting of tubes bound up into a tolerably compact mass, which is usually situated at a little distance from the alimentary canal, into which it opens in the higher orders by a single duct.

In *Vertebrata* we find a considerable advance in complexity of structure; the simple tubular arrangement is lost, and a mass of solid lobules, made up of *acini*, composed of nucleated cells, takes its place. In fishes the contents of these primitive cells is usually oleaginous, but in birds scarcely any fatty matter is present.

The structure and arrangement of the organ in mammals is so similar to that of man that a separate description is not necessary.

DIGESTION AND ABSORPTION.

Human Food.

THE FOOD natural to *man* is a mixture of animal and vegetable products, which may be grouped into albuminous, oleaginous, and saccharine compounds.

The albuminous compounds include both animal and vegetable substances containing nitrogen, as albumen, fibrine, caseine, gelatine, and chondrine.

The oleaginous contain all kinds of fatty and oily matter derived from the animal and vegetable kingdoms; carbon, oxygen, and hydrogen, being the elements found in the group.

The saccharine comprise substances derived entirely from vegetables, as sugar, starch, gum, and woody fibre, all of which contain oxygen, hydrogen, and carbon; the two former elements existing in the proportion to form water.

Nitrogenous food supplies nourishment to the different tissues, and the *non-azotized* compounds furnish means for keeping up the animal heat.

Climate has a marked influence on the requirements for certain kinds of aliment; in warm countries very little oleaginous food is required, whereas in cold regions it forms the principal article of diet. It has been found that dogs fed entirely on sugar and water gradually sink and die in from thirty to forty days, and it is also well known that the want of vegetable diet produces the disease known by the name of scurvy; it thus appears that life cannot be long sustained if the food is composed solely of one of the three groups before mentioned, and, therefore, a mixed diet is best adapted for the requirements of the *human* frame. The teeth of man show, moreover, that he is destined to subsist on a mixed diet, the front, or incisor teeth, being purposed for cutting and tearing

his animal food, the back, or molar, aiding him in crushing and grinding it to a pulp.

Before quitting the subject, it may be remarked that common salt is regarded by most persons as an article of diet absolutely necessary for the continuance and preservation of health, a view which is entirely erroneous, as many individuals, and even whole tribes of the human race, use no more salt with their food than that which is absolutely contained in the solid and fluid aliment on which they live, yet they continue in a state of health, and, therefore, the employment of salt as a distinct article of diet with us is rather a habit than the dictate of necessity.

Human Food.

Group.	Derivation.	Contents.	Chemical composition.
Albuminous compounds.	Animal and vegetable	Albumen, gelatine, caseine, chondrine, fibrine.	O,H,C,N.
Oleaginous compounds.	Animal and vegetable	Fatty matter and oils.	O,H,C.
Saccharine compounds.	Vegetable	Sugar, gum, starch, woody fibre.	O,H,C.
Inorganic matter.	Water and salts (especially common salt) are present in food of almost every description.		

Deglutition.

The process of deglutition comprises a series of movements by means of which the food is propelled down the gullet into the stomach.

When food is taken into the mouth to be masticated it is crushed by the teeth, rolled about by the tongue, and moistened by the saliva. During the process the salivary glands pour out an increased supply of fluid, which becomes intimately mixed with the food, and assists in reducing it to a pulp. As soon as this

operation is completed the tongue carries the bolus backwards till it passes the anterior pillars of the soft palate, the movement by which this is effected being under the control of the will, though the subsequent part of the process of deglutition is quite involuntary. The tongue is next carried still further back and the larynx drawn forward under its root, so that the epiglottis is pressed down on the rima glottidis, preventing anything from passing down into the windpipe. The muscles of the anterior palatine arch then contract, preventing the food from returning into the mouth, and at the same time the posterior pillars close the passage into the nostrils. The morsel, therefore, slips into the pharynx, and is propelled thence down the œsophagus by the contraction of the muscular coats of that canal.

When food has passed down the gullet, and arrives at the cardiac extremity of the stomach, a sort of sphincter muscle there relaxes, and after permitting the aliment to enter, again contracts.

Immediately the food has entered the stomach it is subject to a peculiar movement which causes it to descend the greater curvature towards the pylorus, and then return along the lesser curve to the cardiac portion. After this action has continued for some time, and the food has become sufficiently mixed with the gastric fluid, the contents of the stomach have a tendency to pass towards the pylorus, where a band of muscular fibres, about four inches wide, contracts, and propels the liquid portion of the food into the intestine called the duodenum. When this process is completed the contraction of the fibres ceases, and solid, undigested substances, such as fruit-stones, are permitted to pass. It has thus happened that coins or other foreign bodies, when accidentally swallowed, have passed through the whole length of the alimentary canal.

Digestion having proceeded thus far, some of the nutritive portion of the food is taken directly into

the blood by the vessels in the walls of the stomach, but the greater part passes on into the intestines, where it is acted on by the bile and pancreatic fluid, and is afterwards absorbed by the vessels in the intestinal walls, the nutritive matter being abstracted, and the residue, becoming consolidated, passes down the intestinal canal to be voided from the body.

The Fluids that act on the Food during the passage along the Alimentary Canal.

SALIVA.

During mastication food is thoroughly mixed with saliva, a fluid which is composed chiefly of water, containing a peculiar nitrogenous substance, termed *ptyaline*, greatly resembling caseine. When there is no food in the mouth only just sufficient fluid is poured out to moisten the mucous membrane, but during the act of eating a much larger quantity flows. On an average, about twenty ounces are secreted in twenty-four hours. The use of the saliva is to prepare the food for chemical action, and, by softening it, to assist the process of deglutition. Though its purpose is chiefly mechanical, still it is supposed to influence the food chemically. In an experiment made to support this idea, the œsophagus of a dog was tied, and food, mixed with water, placed in the stomach, was found after some time to be little acted on, though when mixed with saliva, digestion readily took place. Saliva probably converts starch into sugar.

Composition of Saliva.

Water	989
Ptyaline	2
Albumen, soda, and fatty matter	2
Mucus and ash	7
	1000

THE GASTRIC JUICE.

On entering the stomach the food is submitted to the action of the gastric juice, a fluid which is secreted by the glands in the lining membrane, and only poured out when the nerves of the organ are excited by the presence of aliment.

When poured forth for the purposes of digestion, the gastric fluid exudes in minute drops, which, collecting, form a secretion, and mix with the contents of the stomach.

A gun-accident to a man named Alexis St. Martin established an opening in the walls of his abdomen, leading directly to the cavity of his stomach; so that, after numerous experiments on this man, by introducing various substances into the digestive organ and watching the result, several facts were established respecting the action of the gastric juice. The fluid, when analysed, was found to be an acid secretion, composed principally of water, containing about 1·72 per cent. of solid matter. Half the solid components was found to be a peculiar substance called *pepsine*, the remainder being phosphates and chlorides of various salts. The quantitative analysis is (roughly) as follows:

Analysis of the Gastric Juice.

Water	198·18
Pepsine	·90
Phosphate of soda	
,, lime	
,, magnesia	
Chloride of soda	·82
,, lime	
,, magnesia	
Hydrochloric and lactic acids	a trace
	200·00

In appearance, gastric fluid is a viscid and almost colourless liquid, possessing a faint-yellow tint.

The acidity of the juice is due, probably, almost, if not entirely, to the presence of hydrochloric acid, though lactic acid has also been detected in small quantities. The pepsine contained seems to act as a ferment, and for the purposes of digestion a temperature of at least 80° to 90° Fahr. is required; but a very small quantity of gastric fluid, even 1 part in 60,000 of water, is sufficient to dissolve meat. After the food has been reduced and acted on, it is termed *chyme*, and the chyme, therefore, is the fluid product of digestion in the stomach, and passes into the duodenum, where the digestive process is completed, a further change taking place in the intestinal canal, for on entering the duodenum the chyme is acted on by the bile and pancreatic fluid.

THE PANCREATIC FLUID.

The secretion of the pancreas is colourless, slightly viscid, and alkaline, much resembling saliva, but containing more solid matter. It is supposed to act on fatty matter, and render it fit for absorption, by reducing it to a state of "*emulsion.*"

THE BILE.

Bile is secreted by the liver, and poured out into the duodenum. It is a viscid, oily looking fluid, with a dark-greenish colour and bitter taste. Like other secretions, it consists chiefly of water, the solid matter amounting to about 12 per cent.

Analysis of Bile.

Water	88
Biliary matter	8
Mucns, salts of sodium, and lime	4
	100

The biliary matter contains peculiar substances, amongst which cholesterine and bile-pigment may be mentioned. The quantity of this secretion poured out in twenty-four hours has been variously estimated; it may possibly amount to twenty-four ounces in that period. The purposes served by the secretion of the bile are twofold—firstly, it serves the purpose of separating from the blood certain products which require to be eliminated from the system; secondly, it assists the process of digestion, and stimulates certain movements in the intestines, termed the peristaltic action, in order that the undigested residue of the food may be evacuated from the body. It is probable that the bile is not poured into the duodenum unless chyme is present, as in cases of starvation the bile is found to accumulate in the gall-bladder, which, after death from this cause, is usually observed to be quite full of the biliary secretion. Besides the pancreatic fluid and bile, a secretion from the various glands of the intestines themselves is poured out, which acts on and mixes with the chyme after it has passed from the stomach into the intestinal canal.

Chemical Changes that take place in the Food whilst in the Alimentary Canal.

As before mentioned, food consists of albuminous, saccharine, and oleaginous principles, in which the fluids just described produce certain chemical changes.

Animal food breaks up into its constituent parts or fibres, and gradually becomes dissolved; vegetable matter is also digested, though a large portion of the cell-membrane, spiral vessels, &c., existing in plants, remains unchanged.

The *saliva* acts only on the starch, converting it into grape sugar.

The *gastric juice* changes the albuminous part of the food into a low form of albumen, called albuminose

or *peptone.* Some of the saccharine principles, as sugar, gum, &c., are at once absorbed, but the starch and lignine are converted into grape sugar. The oleaginous principles appear to be reduced to fine particles, without being chemically changed by the gastric fluid.

The *pancreatic fluid* acts on starch, and assists in reducing fatty substances to a kind of emulsion, fitting them for absorption.

The *bile* is supposed to exert some influence on the chyme, but the exact nature of the change produced has not been ascertained. It has been stated that the biliary secretion prevents the decomposition of the food, and assists the pancreatic fluid in rendering the contents of the intestine alkaline.

Absorption.

Absorption takes place through the medium of blood-vessels, lymphatics, and lacteals, its object being to introduce into the blood fresh nutritive material to supply the waste of that deposited in the formation or repair of the various animal tissues.

Lymphatics commence in dense networks distributed throughout the body, and convey a fluid called *lymph,* but the source from whence this fluid is derived, remains undetermined. Probably it is supplied from the liquor sanguinis, or watery portion of the blood.

Usually lymph is a clear, colourless liquid, devoid of smell, with a slightly alkaline or saline taste. When microscopically examined, minute corpuscles are found floating in the fluid, which, after passing through the lymphatic glands to larger lymphatic trunks, on its way to the thoracic duct, appears to possess a greater number of corpuscular bodies.

Lacteals are absorbent vessels distributed to the villi in the intestinal walls. Through the coats of *these vessels,* the chyme transudes, or, rather, certain

of its constituents, which become changed in character, and form what is termed *chyle.*

Whilst there is a cessation of the digestive process, the lacteals contain only a clear fluid resembling lymph; but, as soon as chyme is poured into the intestines, absorption takes place, and the fluid becomes turbid, opaque, and milky, acquiring the peculiar characters of chyle.

In appearance, chyle is a white fluid, of an albuminous nature, containing numerous globules of fatty matter, termed by Gulliver, "the molecular base of chyle." As the chyle advances along the lacteals, towards the thoracic duct, it acquires more and more a resemblance to blood, except as regards the colour, which remains unaltered. When withdrawn from the larger lacteal vessels that open into the receptaculum chyli, the chyle is found to coagulate into a soft white mass. The fluid taken from this part of the lacteal system presents an advance of structure; cells or chyle corpuscles are found to be developed in it, and the presence of fibrine gives the power of coagulation.

The chyle corpuscles are similar to the white corpuscles of the blood, and need no separate description.

Relative Analyses of Chyle and Lymph.

	Chyle.	Lymph.
Water	90	96
Albumen	4	1
Fibrine and salts	1	½
Fatty matter	4	a trace.
Animal extractive	1	2½
	100	100

The chief difference between chyle and lymph consists in the presence of a much smaller proportion of solid matter in lymph, and in the almost entire absence of fatty matter.

The fluid in the thoracic duct, therefore, consists of

a mixture of lymph and chyle, partaking of the character of each fluid. The quantity of this mixed fluid poured into the blood daily is about equal to two thirds of the whole mass of the sanious fluid in the body. Absorption through the walls of the blood-vessels themselves, occurs in the capillaries of the stomach and intestines. These vessels absorb the *liquid* portion of the food without selection or choice, and, therefore, food in a fluid state is much more rapidly taken into the current of the blood than is the case with solid aliment. The process of digestion and absorption having been traced, our next step will be the examination of the circulating fluid or blood into which the digestive products are carried.

THE BLOOD.

THE *blood*, or nutritive fluid of the body, is formed at the expense of the food, and conveyed throughout the frame by systems of vessels called veins and arteries.

The different tissues draw from the blood the principles that are required for their nutrition; at the same time, the various products of decay are removed and carried away in the circulating fluid.

The blood, therefore, contains effete, as well as nutritive matter.

The animal tissues require oxygen for their support; and this element is conveyed to them by the blood, being introduced into that fluid through the medium of the lungs. The result of the action of oxygen on the tissues is carbonic acid, which is absorbed by the blood, and carried to the lungs and skin for elimination.

The purposes, served, therefore, by the circulating fluid are threefold; *firstly*, it affords a supply of *material for* the maintenance of the body; *secondly*, it

conveys oxygen to the various tissues; and *thirdly*, it removes the effete or refuse matter set free by the disintegration of those tissues.

The blood being sent forth from the heart into a system of vessels called *arteries*, is distributed by them throughout the body, and comes into close relation with the tissues, and having given up to them certain of its constituents, is again collected by another system of vessels, termed *veins*. It is obvious, therefore, that in various parts of its course the blood must present very different characters.

Physical and Chemical Structure of the Blood.

The colour of the blood is bright scarlet if drawn from an artery; dark purple, or nearly black, when drawn from a vein.

Deviations from this rule take place under various circumstances; thus in hot climates, arterial blood even is of a dark colour; and an imperfect supply of air to the lungs produces the same effect.

The temperature of the fluid whilst in the body is usually about 100° Fahr., and its specific gravity about 1055, water being taken as 1000. When fresh drawn, a faint odour is emitted, and some persons have imagined that a slight vapour is exhaled.

As blood flows from the body, it appears to be a homogeneous, viscid fluid, but when examined microscopically, it is found to consist of a colourless liquid (the liquor sanguinis), in which float numerous small globular bodies, called *blood corpuscles*, most of them being red, but a few colourless. This condition only applies to blood whilst in the body, or after it is just drawn, as a change begins to take place as soon as it leaves the vessels in which it flows. When blood is drawn and permitted to stand, *coagulation* takes place, that is to say a dark-coloured clot forms, from which gradually oozes a yellowish liquid. The clot is called the *crassamentum*, and the yellow liquid the serum.

The process may be thus explained: the liquor sanguinis consists of a serous fluid, holding *fibrine* in solution, and, as before stated, a number of corpuscles float freely in the fluid. When at rest, fibrine has a tendency to become solid, so that if blood is drawn and permitted to stand, the fibrine coagulating, entangles the serum and corpuscles in its substance. But the process does not stop here; after the fibrine has coagulated it contracts and squeezes out the serum, but retains the corpuscles.

The *crassamentum*, or clot, therefore, is composed of a network of fibrine, in the meshes of which the corpuscles are entangled, giving the whole mass a dark red colour.

The *serum* is in fact the liquor sanguinis deprived of its fibrine. Serum contains albumen, and on that account is capable of being coagulated by heat. With regard to the coagulation of blood, as a general rule it is retarded by cold, but promoted by rest and free access to air.

Fluid Blood.

Blood in a fluid state	Liquor sanguinis	Water. Fibrine. Albumen. Salts.
	Floating corpuscles ...	Red corpuscles. White corpuscles.

Coagulated Blood.

Blood when coagulated	Crassamentum or clot...	Fibrine. White and red corpuscles.
	Serum	Water. Albumen. Salts.

Blood corpuscles.—Two varieties of corpuscles exist, red and white. As seen under the microscope, *they* are flattened cells, of a circular form, the red pre-

senting either a bright or dark central spot, as they are brought in and out of focus.

Red corpuscles are present in large numbers in the blood; their diameter varies from $\frac{1}{3000}$th to $\frac{1}{4000}$th of an inch, and their thickness is about $\frac{1}{10,000}$th of an inch. When examined singly, they appear almost colourless, and it is only when viewed in numbers that they exhibit the florid colour.

White corpuscles are much less numerous than the red, not more than one white to fifty coloured being present in human blood. As a rule, their diameter is greater than that of the red corpuscles, and may be estimated at $\frac{1}{2300}$th of an inch. The form and appearance of the corpuscles, both red and white, varies greatly, according to the character of the liquid in which they float. The colour of the blood may even be altered by a change of form in the corpuscles. Thus it is probable that the difference in colour of arterial and venous blood depends on an altered form of the corpuscles contained. When subject to the action of water, corpuscles swell, become convex, or even round, and may at length burst.

With regard to the structure of *red* blood corpuscles, they may be considered to be cells, provided with an elastic cell wall, enclosing apparently homogeneous contents impregnated with red colouring matter, called hæmatine. The *white* corpuscles, however, seem to contain granular matter, the cell wall being scarcely ever visible unless the corpuscles are treated with water, or diluted acid, when the cell becomes distended, and the wall separated from the enclosed matter.

If the minute vessels in the web of a frog's foot are examined, both varieties of blood corpuscles will be seen hurrying along in the current of the blood, the red moving rapidly in the centre of the stream, the white, passing more slowly along the sides of the vessels.

The functions served by the blood cells have not

been determined, nor has it been ascertained how or where they are formed. The most probable source of their origin is, that they are formed from the chyle and lymph corpuscles, poured into the blood from the *thoracic duct;* as in the general current of the blood, corpuscles in intermediate stages of development are always found; and indeed, occasionally the fluid in the thoracic duct has a red tinge, supposed to be due to the commencing development of hæmatine in the interior of the chyle corpuscles. Doubtless the blood cells are continually undergoing decay, whilst others are being generated to supply their place; and most likely they are derived in the manner just noticed, for they are proved not to be developed by fission of the pre-existing corpuscles.

Chemically, the blood may be regarded as an alkaline fluid, composed principally of water, containing a certain amount of solid matter. Amongst the more important components of the solid matter, hæmatine may be mentioned. It is stated to contain iron, and is found mixed with globuline, the compound being termed *cruor*.

Chemical Composition of the Blood.

Blood	Water			795
	Solid matter	Corpuscles	Hæmatine	8
			Globuline	140
			Iron	1
		Fibrine		2
		Albumen		40
		Fat		2
		Salts		8
		Extractive matter		4
				1000

The difference between venous and arterial blood, as regards colour, has been already noticed; but

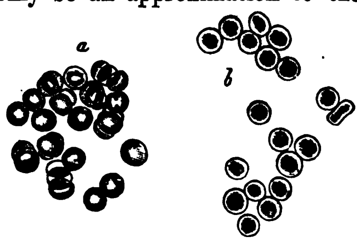
other differences exist; thus, in the arterial fluid, there is less albumen and more fibrine than in the venous. Moreover, the specific gravity is lower, the amount of red corpuscles greater, and probably, the proportion of oxygen larger in the arterial blood.

Piles or rouleaus of red corpuscles, exhibiting a peculiar tendency that these corpuscles possess of running together and adhering by their broad surfaces.

The quantity of blood in the body.—The precise determination of this point is difficult. It has been found that if numerous vessels in the body of an animal are opened, and the blood permitted to pour from them, a large quantity can be collected. In this manner it has been estimated that the weight of the blood is to that of the body:

As 1 to 12 in an ox,
„ 1 to 18 in a horse,
„ 1 to 16 in a dog.

These data can only be an approximation to the truth; for however freely the vessels are opened and the blood permitted to flow, still, a large quantity must remain in the body. Nor can such an experiment be made on the human subject, except, indeed, in cases of execution. It is stated that as much as 24 lbs. of blood were taken from a decapitated female. Applying the results of experiments on other animals to the human body, it appears that the amount of blood contained may be estimated at 18 lbs. to 20 lbs.



Blood Corpuscles: *a* and *b*, the two different appearances of red corpuscles.

Blood in other Animals.—In many of the lower animals the digestive apparatus communicates freely with the general cavity of the body, so that the whole structure is bathed in the immediate products of digestion without the intervention of any system of blood-vessels.

In the higher *articulata*, however, the circulation becomes more perfect; a system of vessels exists in which the blood flows, and the circulating fluid more resembles that of the vertebrata, though the corpuscles present a different form, being *oat*-shaped, and the colour of the blood unlike that of mammals, being either nearly white or tinted blue and green. One order of articulate animals alone presents an exception to this rule; in certain worms the blood is of a distinctly red colour, and the animals are usually designated as "the red-blooded worms."

True blood is always contained in a definite system of tubes or vessels, and cannot pass out of them unless their walls are ruptured, though the essential portions of the blood may exude. Thus, in inflammation, the corpuscles collect together in the interior of the blood-vessels and cause an obstruction at one particular spot. The serum and the *contents* of the corpuscles transude, and tinge the surrounding parts red; but the corpuscles themselves cannot pass without actual rupture of the sides of the vessels in which they are contained.

Vertebrata possess red blood similar to that of man, but the size and shape of the corpuscles varies in different kinds of animals.

In cold-*blooded* vertebrata the blood is thinner and more watery, containing less solid matter, with very few corpuscles, but those that *are* present are of large size.

In reptiles and *fishes* the number of white corpuscles preponderates greatly over that of the red. In form the corpuscles are oval discs, with a central elevation on both surfaces; the diameter varying from *the* $\frac{1}{1000}$*th* to the $\frac{1}{400}$th of an inch.

In birds the shape of the corpuscles resembles that

of the corpuscles found in the blood of fishes; but the red corpuscles are present in excess, and the average amount of solid matter greater even than in the blood of mammals.

In mammals the red corpuscles are shaped as in man, but for the most part they measure less in diameter. The camel tribe exhibits an exception to this rule, as the corpuscles in the blood of these animals are of an oval form.

THE HEART AND BLOOD-VESSELS.

THE heart is the organ by means of which the blood is propelled in its course through the body. As it is necessary for the circulating fluid to be exposed to the action of the air, the heart consists of two distinct parts; the one side receives venous blood, and propels it into the lungs; the other receives the fluid after it has been aërated, and distributes it through the arteries to certain parts of the body. The heart is composed of striped muscular bands, arranged in a spiral form; and the whole organ is suspended free to move in a bag of fibro-serous membrane, called the pericardium. The position of the heart in the chest is oblique, the base being directed upwards and backwards; the apex downwards and forwards, pointing to the space between the fifth and sixth ribs. The whole organ is more to the left than to the right, though part of it is behind the sternum. It is divided into four chambers, two on each side, which communicate; but no direct communication exists between the right and left sides of the heart. The heart, therefore, is a muscular structure, conical in form, enclosing two cavities, separated completely by a central vertical septum or partition, each cavity, right and left, being again divided into two chambers, which receive the name of auricle and ventricle; the former *situated* above the latter.

THE RIGHT SIDE OF THE HEART has two chambers, the right auricle and right ventricle, which communicate freely by an opening called the auriculo-ventricular opening.

On examining the *right auricle*, an irregular cavity is found, from which projects a small pouch, termed the "appendage." The internal surface of the auricle is lined with a smooth, shining membrane, continuous with the lining membrane of the veins which communicate with the chamber. Opening into the auricle are the two great veins which bring the blood *to* the heart, termed the *superior* and *inferior venà cava;* and, besides these, the coronary veins, which return the blood from the structure of the heart itself, also open into the auricle. The opening between the auricle and ventricle is sufficiently large to permit the passage of three fingers. It is guarded by a valve called the *tricuspid* valve, so named from its consisting of three curtains of tendinous structure, which together are capable of closing the auriculo-ventricular opening during the contraction of the ventricle.

The *right ventricle* forms the greater part of the anterior surface of the heart. Internally the surface is covered with muscular bands, from which stretch tendinous cords to the extremities of the curtains of the tricuspid valve. The shape of the ventricular cavity is pyramidal; and leading from it by a circular orifice, is the "pulmonary artery," which conveys the blood *to* the lungs. Guarding the mouth of this vessel are the semilunar valves, composed of three semicircular folds, each attached by its convex border to the side of the artery just where it joins the ventricle.

THE LEFT SIDE OF THE HEART contains also two chambers, an auricle and ventricle, communicating by an auriculo-ventricular opening, guarded by a valve called the "*bicuspid*" or "*mitral.*"

The *left auricle* is smaller than the right, but provided with thicker muscular walls. Examined internally, the cavity is found to be provided with an auricular appendix, similar to the right; and, opening

into the auricular chamber are *four* veins, termed the *pulmonary* veins, bringing the arterial blood *from* the lungs. The auriculo-ventricular opening is oval in shape, smaller than on the right side, and guarded by the *mitral* valve; so called, from its being formed of two flaps or curtains of tendinous structure, their extremities being attached to tendinous cords in the same way as described respecting the tricuspid.

The *left ventricle* is provided with very thick muscular walls, enclosing a cone-shaped cavity; the interior presenting muscular or fleshy columns, and a small circular orifice, guarded by three semilunar valves, leading into the *aorta* or principal artery of the body.

Blood-Vessels.

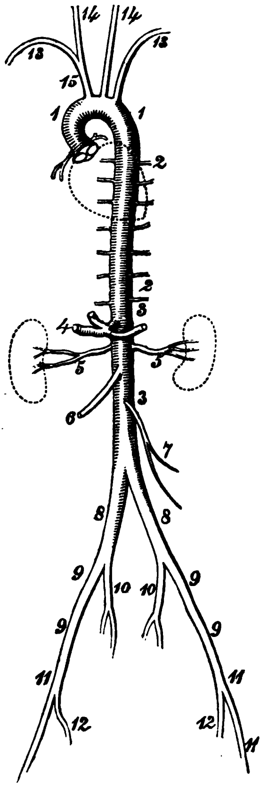
Blood-vessels are tubes by which the blood is carried through the body. They may be divided into two systems, venous and arterial; the former conveying the blood to the heart, the latter carrying it from that organ to different parts of the frame. These two systems of vessels communicate by means of very minute tubes, called capillaries, through the walls of which the influence of the circulating fluid is exerted on the tissues.

ARTERIES (so called from the old notion that they contained air), are vessels which distribute the arterial blood to the system. The walls of arteries possess the power of contracting on their contents, thus aiding the heart's action in propelling the blood onwards in its course. The vessels are contained in a loose sheath of areolar tissue, their walls being composed of three layers, external, middle, and internal.

The *external coat* is firm, tough, and strong, made up of fibrous and elastic tissues, giving the greatest strength to the arterial wall.

The *middle coat* is thick, and constitutes the chief

part of the wall, being composed of numerous layers of yellow elastic tissue, disposed in a circular manner round the vessel, and giving the power of contractility to the artery.



The *internal coat* is a delicate, transparent membrane, giving a smooth lining to the interior of the vessel. It is composed of epithelial scales, covering a striated membrane of fine fibres of elastic tissue. The larger the vessels the thicker their walls. They are totally unprovided with valves, and divide and subdivide till they end in minute vessels, termed capillaries.

The *aorta* is the largest artery in the human body; arising from the left ventricle of the heart, it curves upwards, forming an arch, from which the vessels that supply the head, arms, and upper part of the body spring. Continuing down, nearly in the median line, the aorta passes through the thorax into the abdominal cavity, where it divides into two *iliac* arteries, each again sub-

1. The arch of the aorta.
2. The thoracic aorta.
3. The abdominal aorta.
4. Branch distributed to the spleen, stomach, and liver (cœliac axis).
5. Renal arteries.
6, 7. Arteries to the intestines (*mesenteric arteries*).
8. Common iliac artery.
9. External iliac.
10. Internal iliac.
11. Femoral artery.
12. Deep femoral.
13. Subclavian.
14. Carotid.
15. Innominate artery.

dividing into *external* and *internal iliac*, which again give off other arteries to supply the legs and lower parts of the body. In its course through the thoracic and abdominal cavities the aorta gives off numerous large branches to all the important organs, as the liver, stomach, kidneys, spleen, &c.

The arteries which arise from the arch and upper part of the aorta are given off at right angles to the main trunk, so that the force of the blood coming from the heart may be diminished. But in other parts of the arterial system, when arteries branch at a greater distance from the heart (where the impulse is not more than sufficient to continue the circulation), the direction of the branches is oblique, so that no resistance is offered to the current of blood.

Capillaries are delicate vessels, permeating almost every part of the body, arranged in a close network, the branches being tolerably uniform in size. The diameter of these vessels rather exceeds that of the blood corpuscles, the coats consisting of a very delicate membrane, through which the nutritive part of the blood acts on the tissues. After this fluid has thoroughly traversed the texture, the capillary vessels convey it to another system of vessels, called veins. The capillaries, therefore, communicate directly with and connect the arterial and venous systems.

VEINS are vessels which ramify through the body in a manner similar to arteries, but differing from them in structure and proportionate number. Veins have thinner coats than arteries, and want also the elasticity possessed by those vessels, but they are provided with internal valves of a semilunar form.

The walls are composed of three coats, external, internal, and middle.

The *external coat* is the thickest, consisting of areolar tissue, and in large veins of unstriped muscular fibre also.

The *middle coat* is much thinner than the corre-

sponding coat in arteries, and though the *elastic* fibres exist, they are arranged in a longitudinal instead of a circular manner. A layer of *muscular* fibres, however, *has* a circular arrangement.

The *internal coat* is a thin, smooth membrane, composed of epithelium and elastic fibre, lining the interior of the vessels.

In the veins, a means of preventing the reflux of blood exists in the form of valves. These valves are semilunar folds of lining membrane, two such folds usually occurring together. They do not prevent the current of blood passing in the proper direction, as the flaps lie flat against the walls of the vessels; but directly any cause tends to drive the fluid back, the valves bulge out, and meeting in the centre close the channel.

Small veins are not provided with valves, and they are also found wanting in the largest, as the venæ cavæ, pulmonary and hepatic veins.

One single exception with regard to the structure of veins and arteries takes place, or rather there exists a vessel having the structure of an artery which carries venous blood; and there are also certain vessels with the structure of a vein which carry arterial blood. This is the case in the *pulmonary artery and pulmonary veins.*

The *pulmonary artery* carries venous blood *from* the heart *to* the lungs, and the *pulmonary veins* bring back the blood *from* the lungs *to* the heart. Veins of large size accompany large arteries in their course, and frequently two veins run with smaller arterial vessels.

The whole capacity of the venous system is greater than that of the arterial, two or three times as much blood being contained in the veins as in the arteries, in ordinary circulation.

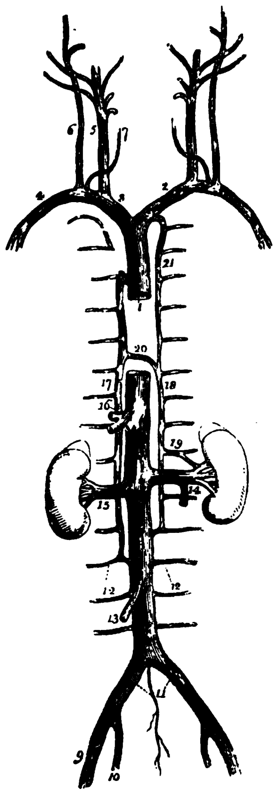
The venous system collects its branches into two great veins, the vena cava superior and inferior. The former, collecting the blood from the head and upper *extremities,* pours its contents into the right auricle;

the latter, receiving the blood returned from the liver, stomach, and other visceral organs, and also from the whole of the lower part of the body, opens likewise into the right auricle. The superior cava is very short, but the inferior is of considerable length, and accompanies the descending aorta, and divides in a similar manner into iliac vessels.

The course of the Blood through the Heart and Blood-vessels.

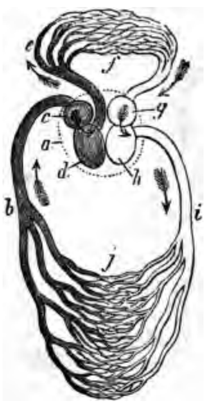
The blood constantly circulates through the living body at a certain rate and in a certain direction—a fact that was first demonstrated by Harvey in the year 1628.

The course of the blood may be thus described:—The two great veins, the vena cava superior and inferior, collecting the blood from the upper and lower parts of the body, pour it into the right auricle of the heart. The fluid passes from that cavity through the auriculo-ventricular opening into the right ventricle. From thence it is propelled into



Veins of the Trunk: 1, superior vena cava; 2, 3, left and right vena innominata; 4, suuclavian vein; 5, 6, 7, the internal, external, and anterior jugular veins; 8, the inferior vena cava; 9, 10, the external and internal iliac veins; 11, the common iliac veins; 12, lumbar veins; 13, spermatic vein; 14, 15, the renal veins going to the kidneys; 16, hepatic veins; 17, 18, 19, 20, 21, azygos veins.

the pulmonary artery, and carried by that vessel to the lungs, where it is exposed to the influence of the air. After having circulated through the lungs, the blood enters the pulmonary veins which bring it back to the heart, pouring it into the left auricle. From that chamber it passes into the left ventricle, and is finally driven thence into the aorta, and distributed to the body, after which it is again collected by the veins, and brought back to the right side of the heart, to go over the same course again.



Ideal view of the Circulation in Mammals and Birds.

a. The heart, containing four chambers, *c, d, g, h.*
c. The right auricle.
d. The right ventricle.
g. The left auricle.
h. The left ventricle.
b. The vena-cava (superior and inferior, represented as one vessel for the sake of illustration), bringing the venous blood from the system and pouring it into the right auricle (*c*), from whence it passes into the right ventricle (*d*), and thence into (*e*) the pulmonary artery.
e. The pulmonary artery conveying the venous blood to the lungs (*f*).
f. The capillary vessels of the lungs, leading to the pulmonary veins in the direction of the arrow, bringing the arterial blood back to the heart, pouring it into the left auricle (*g*), from whence it passes into the left ventricle (*h*), and thence into the aorta (*i*), to be conveyed to the system at large through the arteries and distributed to the tissues through the capillaries (*j*), where it is re-collected and carried back by the veins to the heart again.

Causes of the Circulation through the Heart.—The contraction of the chambers of the heart, assisted by the elasticity of the coats of the arteries, produces that onward flow of the blood through the body termed circulation. Though composed of striped muscular fibre, the heart is involuntary in its action. It is a very irritable organ, that is, can be easily excited to contract and expand; but to what this power is due has yet to be determined. Some have imagined that the blood exerted a peculiar stimulating influence on the lining membrane, which caused the contractile action; but

this is disproved by the fact that after the heart has been removed from the body, a slight irritation will cause a renewal of its movements in their regular order of succession. Especially is this the case in fishes and amphibious animals; the heart of a frog for example, retains the power of pulsating many hours after its detachment from the body. Hence, it must be concluded that the irritability of the heart is an endowment of its own, existing in the structure itself. The brain and spinal cord, however, exert some influence on its action; for though experiments have proved that the gradual removal of either, or both these great nervous centres from the body of inferior animals, will not arrest the heart's action, still their sudden destruction produces a cessation of the pulsations. Distributed through the substance of the heart are numerous small nervous ganglia, which may possibly act as so many centres or organs for the production of the motive power.

In propelling the blood, the auricles and ventricles alternately dilate and contract; the contraction of the auricles is simultaneous and precedes that of the ventricles; the contraction of the ventricles is also simultaneous, the dilatation of the chambers following the same rule. To describe the heart's action: Let it be supposed that the walls of the auricles and ventricles are relaxed, and their cavities beginning to dilate; blood pours into the right auricle from the venæ cavæ, a portion passes on into the ventricle, but the auricle becomes filled first, and fully distended; immediately this happens, it quickly contracts, forcing the blood into the ventricle, which, being thus filled, also contracts, driving the blood into the pulmonary artery. During the auricular contraction, the blood is prevented from returning into the veins, by a contraction at the mouths of these vessels, and any reflux of blood from the ventricle into the auricle is hindered by the tricuspid valve closing the auriculo-ventricular opening; for, during the contraction of the ventricle,

the fleshy columns in the interior also contract, pulling the folds of the valve away from the walls of the cavity, by means of the tendinous cords, and the blood, getting behind the valvular flaps, forces them into the opening. In the pulmonary artery, the blood is carried on to the lungs, any regurgitation being prevented by the closure of the semilunar valves. Simultaneous with this action of the auricles and ventricles on the right side, the same kind of action goes on in the left side of the heart; the blood comes from the pulmonary veins into the auricle, which, getting quite full, contracts and fills the ventricle, whence the fluid is propelled into the aorta.

Directly the auricles have contracted, they begin to dilate again, and to be filled with blood; whilst they are filling, the ventricles are performing their contractions; this being ended, the ventricles also expand, and blood flows into them from the auricles, bringing the action to the point at which the description commenced.

HEART SOUNDS.—On listening to the chest, two sounds, following each other in quick succession, will be detected. These sounds are caused by the heart's action; the first is dull and prolonged; the second, sharp and short, followed by a pause, when the sounds are again repeated. The first sound is caused by the contraction of the ventricular walls, and the closing of the tricuspid and mitral valves; the second arises from the shutting of the semilunar valves on both sides of the heart. If a period of time be assigned to this "rhythm" of the heart, it will be found, on dividing it into four equal portions, that two parts are occupied by the first sound, one by the second, and one by the pause. The pulse at the wrist follows almost immediately the production of the first sound, and, at the same time, the heart has an impulse given to it by its action, which tilts the *apex* forwards against the wall of the chest.

Frequency and force of the Heart's Action.—The ventricles of the human heart can propel about three ounces of blood at one stroke; the force with which they act being estimated at about equal to $\frac{1}{50}$th of the weight of the body for the left, and about half that power for the right ventricle. The force of the current of blood in arteries near the heart, has been determined by introducing the end of a tube, and permitting a column of blood to rise, and this experiment, performed on the carotid of a horse, showed that the blood would rise ten feet, from the force of the circulation. From similar experiments on various animals, it may be calculated that the human heart has the power of raising a column about seven or eight feet high, equal to about four or five pounds weight.

The number of contractions made by the heart in one minute varies according to age, sex, and stature; health or disease, muscular exertion, mental emotion, &c., produce considerable differences. In a state of health the number of beats per minute is—

In a newly born infant	130 to 140.
During the third year	95 „ 105.
From 14 to 21	75 „ 85.
„ 21 „ 60	70 „ 75.
In old age	75 „ 80.

In the male and female sex, persons of the same age being taken, *cæteris paribus*, the beats in the female will exceed those in the male by from ten to fourteen per minute; and with regard to height, the pulse will be found to be more rapid in short than tall people.

Movement of the Blood in the Arteries.—The contractility of the arterial coats enables them to exert a propulsive force supplementary to the heart's action. Unless this was the case, it is evident that the blood would be propelled violently, and in sudden gushes through the aorta and great vessels arising from it, but slowly and with difficulty through vessels

remote from the heart's influence. To obviate this inequality, all arteries are provided with elastic walls, the smaller vessels possessing greater elasticity than the larger; an equable flow of the circulating fluid is thus produced, and the pressure on the coats of the arteries more equally diffused than would otherwise be the case. The rate of movement of the blood through the arteries has been estimated at about twelve inches per second; the lateral pressure on their walls about sufficient to support a column of mercury six inches high. If the finger is placed on the radial artery at the wrist, the expansion of the coats will be felt; still, the feeling of pulsation is due not only to this cause, but also to the elongation and elevation of the artery from its bed at each beat of the pulse.

Movement of the Blood in the Capillaries.—The movement of the blood through the arteries, is clearly caused by the propulsive force exerted by the heart, aided by the elasticity of the walls of the vessels themselves, but the cause of the circulation through the capillaries is not so manifest. Possibly the blood is propelled into them with sufficient power to maintain its flow through their channels, though some additional force may exist in these vessels independent of this *vis-a-tergo.* Certain it is that the heart of cold-blooded animals may be removed, or their brains partly crushed (sufficiently so to destroy life) without arresting the circulation in the capillaries. Still the nervous system must have at least some influence on the capillary circulation, as exemplified in the act of blushing. One other cause has been assigned as accessory, namely, a certain sucking power, supposed to be exerted through the venous system, due to the dilatation of the chambers on the right side of the heart. The movement of the blood through the capillary system (which is 400 times as great in area as the arterial) is extremely rapid, the blood passing

onward being poured into the small veins formed by the union of the minute capillaries.

Motion of the Blood in the Veins is slower than in the arteries, inasmuch as the capacity of the venous system is three times as great as that of the arteries; and as the current of venous blood has to ascend from the lower part of the body to the heart, the onward movement is retarded by the force of gravity exerted on the columns of blood in the veins, though the valves, with which the venous trunks are provided, prevent any return of the blood when once past them.

The cause of the onward movement of the blood in the veins is chiefly due to the *vis-a-tergo*, resulting from the force with which the heart and arteries drive the blood through the capillaries. But, besides this power, it is possible that the expansion of the chambers on the right side of the heart exerts a sucking force, drawing the blood upwards, and the act of inspiration may also assist the process; a partial vacuum being formed in the chest, probably induces an increased flow of the blood through the vena cava. There is still another influence that certainly aids the venous circulation to a great extent, the compression exerted on the veins by the muscles when in action—a fact which is well illustrated in the injurious effect produced by sudden movements in persons suffering from diseased heart.

Any obstruction to the passage of blood through the lungs, or heart, will act by impeding the flow of blood into the right side of the organ, and be followed by venous congestion, which may result in the pouring out of the fluid portion of the blood through the walls of the vessels, constituting dropsy, a sequence so commonly seen in cardiac diseases.

*** For a description of the *heart*, *blood-vessels*, and *circulation* in the *Lower Animals*, see p. 116.

RESPIRATION.

Anatomy of the Lungs and Windpipe.

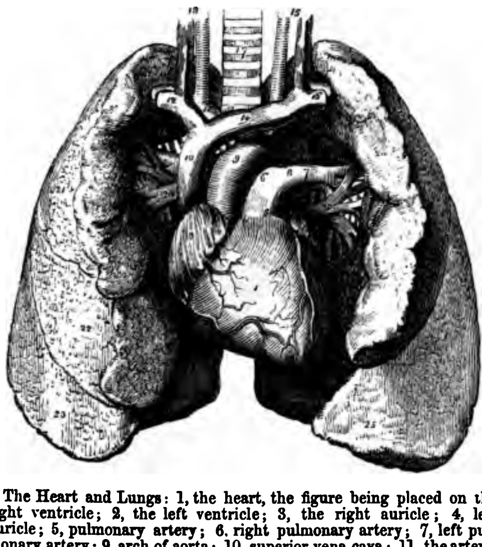
In the human subject the lungs or organs of respiration are complex structures, by means of which the blood is exposed to the action of the air.

The lungs are two in number, conical in form, and invested by a membrane called the *pleura.* The right lung is the larger, and is divided into three lobes; the left is only divided into two. Each lung is supported by its "root," which is formed by the pulmonary vessels opening into the heart and the great bronchial tubes communicating with the *trachea* or windpipe.

The *Trachea* is a membranous tube of fibro-muscular structure, surrounded by about fifteen to twenty fibro-cartilaginous rings, deficient at the posterior part, the rings being connected by yellow elastic fibrous tissue, and the whole canal lined with mucous membrane, covered with ciliated epithelium, and moistened by secretions from numerous tracheal glands. At the upper part the trachea communicates with the larynx, which contains the organs of the voice, and leads to the mouth. At the lower extremity the windpipe divides into two tubes, called *bronchi*, the right being larger than the left, and passing into the lung almost at right angles to the trachea; the left descends obliquely, and passes under the arch of the aorta to reach the left lung. On entering the lungs the bronchi divide and subdivide into numerous small branches, like the branches of a tree, till they are no larger than the $\frac{1}{40}$th or $\frac{1}{30}$th of an inch in diameter; the cartilaginous rings which are observed in the trachea become incomplete, and finally terminate and are lost altogether in the bronchi. When near their termination, the bronchial tubes become very minute, and open into little closed sacs or air vesicles, a cluster of these cells

forming a lobule. The diameter of the cells is about $\frac{1}{200}$th of an inch, and it has been calculated that nearly 18,000 air cells are grouped round each terminal bronchus, so that the whole number in the lungs would amount to about 6,000,000.

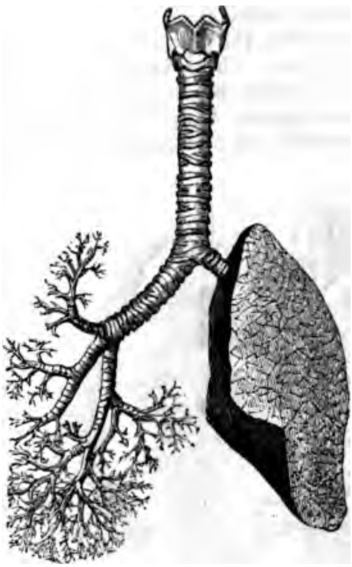
Entering the lungs with the bronchi are the pulmonary arteries and veins. The arteries divide into numerous minute capillaries, which ramify between the air-cells in such a manner that both sides of the vessels are in contact with the air-vesicles. The pul-



The Heart and Lungs: 1, the heart, the figure being placed on the right ventricle; 2, the left ventricle; 3, the right auricle; 4, left auricle; 5, pulmonary artery; 6, right pulmonary artery; 7, left pulmonary artery; 9, arch of aorta; 10, superior vena cava; 11, the arteria innominata, and, in front, the vena innominata; 12, subclavian vein; 13, 15, carotid arteries and jugular veins; 17, the trachea; 19, 20, the bronchi and pulmonary vessels forming the roots of the lungs; 22, 23, 25, lobes of the right and left lungs.

monary veins arise from these capillaries, and pass out at the root of the lung to enter the heart. The whole mass of pulmonary tissue, therefore, consists of bronchi

surrounded by air-cells, between which the capillary plexuses are disposed, the walls of the capillaries being closely surrounded by the air-vesicles, and in immediate contact with their walls; so that between the circulating fluid and the atmospheric air nothing but the thin walls of the air-cells and capillaries intervenes. Lining the inner side of the thoracic cavity, and reflected thence on to the external surface of each lung, investing it very closely, is a serous membrane, termed the *pleura*, constituting a separate lining on each side of the thorax, and the approximation of the two reflected pleuræ forming a septum, which divides the chest into two pulmonary cavities, quite distinct from each other, so that the injury or collapse of one lung does not interfere with the action of the other.



The Trachea and Lungs in the Human Subject: The left lung is represented untouched; the right shows only the bronchus and its ramifications.

The fibrous coats of the larger bronchial tubes contain muscular fibre, but in the smaller ramifications the muscular structure is wanting. A considerable degree of contractile power, therefore, exists in these tubes, which may be called into action by mechanical stimuli or nervous excitement; but the exact purpose served by this contractile power is scarcely certain;

it may assist the contraction of the lungs in expelling air and mucus, or it may help to regulate the supply of air to the air-vesicles.

Movements of the Lungs during respiration.

The movements by which the air is drawn into and forced out of the lungs are termed the act of inspiration and expiration. The chest, lined by the pleura, is a cavity completely closed on all sides, shut in by the ribs and intercostal muscles, the diaphragm forming the floor; when this cavity expands, the ribs rise, and the diaphragm descends from a convex form to nearly a plane surface. The first and upper ribs in women have a greater freedom of motion than in men, causing the breast to rise at each inspiration; whereas in men the chest expands more generally, especially at the lower part. In a state of health the lungs, heart, and great vessels fill the cavity of the chest, so that when the muscles, acting on the ribs, enlarge that cavity, the lungs also expand, and air rushes down the trachea through the bronchi into the pulmonary structure. Unless this took place, a vacuum would exist between the wall of the chest and lungs; consequently, the tendency to form the vacuum causes the pulmonary tissue to expand. If the wall of the thorax is perforated by a wound, and air admitted into the pleural space, the lung on that side ceases to act, as at each expansive movement of the chest the air rushes in through the wound, and prevents the formation of the vacuum. Should it happen that both pleural cavities were wounded, as might be the case from the traversing wound caused by a sword-thrust, both lungs would collapse, and asphyxia, or death by suffocation, would ensue.

After the act of inspiration has taken place, the air is forced out again by the expiratory movements; and this is effected by the relaxation of the external intercostal muscles, and the contraction of the internal in-

tercostals, drawing down the ribs, and diminishing the size of the thoracic cavity, aided by the elasticity of the walls of the chest, and the return of the diaphragm to its arched form. The lungs, therefore, pressed thus on all sides, diminish in bulk, the elasticity of the pulmonary tissue itself assisting the contraction, and forcing the air out through the air passages. Thus air is drawn in and expelled alternately from the chest, the movements being repeated about twenty times in a minute in a healthy person; but in some diseases the respiratory movements follow in succession much more rapidly.

The "*vital capacity*" of the chest is measured by the quantity of air that can be forced out at one expiration, and varies usually in proportion to the height of the individual. Thus, the capacity of the chest in a man of five feet high would be about 174 cubic inches, and, under similar circumstances, in a person six feet in height, 260 cubic inches.

Of the Air taken into the Lungs during Respiration.

Air taken into the chest at one inspiration is not wholly expelled by the following expiration, for if this was the case, the fresh air would only reach the larger bronchial tubes, without penetrating to the smaller branches or air-vesicles. This is obviated by the mixture of the fresh air with the impure or "*residual*" air remaining in the chest, due to that mutual diffusion that takes place when two gases come into contact.

The action of the atmospheric air on the blood passing through the pulmonary capillaries is the most important feature in respiration. The venous blood, charged with carbonic acid, is conveyed to the lungs by the pulmonary arteries, and distributed to the capillaries; the air (which is composed of oxygen and nitrogen), entering the minute air-cells, acts on the blood through the walls of the cells and capillary

vessels, giving up its oxygen to the venous blood, that gas being replaced by a rather smaller bulk of carbonic acid evolved from the blood. Thus, the oxygen passes into, and the carbonic acid out of the venous blood by what is termed endosmose and exosmose. The oxygen admitted does not immediately become changed into carbonic acid, but converts the venous into arterial blood, which is returned to the heart, and distributed by the arteries to the tissues on which it acts, the oxygen uniting with the carbon to form carbonic acid. In the same way, the carbonic acid exhaled is brought *to* the lungs for elimination, and not formed in the organs themselves. In proof of this, experiments have shown that when frogs or snails are made to breathe hydrogen, carbonic acid is evolved and given off to a considerable amount.

The quantity of this gas exhaled by a human being varies so much according to the influence of temperature, age, sex, health, sleep, repose, &c., that no very exact standard can be affixed; roughly it may be stated to equal eight ounces troy per diem, the amount given off during the waking state exceeding that evolved during sleep.

Besides carbonic acid, nitrogen and watery vapour are given off from the lungs. With regard to the nitrogen, it seems probable that the quantity evolved is balanced by an equal quantity absorbed with the oxygen. The air, therefore, that is exhaled differs from that which is inspired, inasmuch as it contains carbonic acid in the place of oxygen, and is impregnated with a large amount of watery vapour, as much as from six to twenty-seven ounces being exhaled during the day.

Influence of the Nervous System on Respiration.

Though the respiratory movements are to a great extent under the control of the will, their involuntary succession of continued actions depends on nervous

influence. When air is withheld, a certain feeling, called the "besoin de respirer," arises, caused by irritation of the great "*vagus*" nerves, which are the excitor nerves of the lungs; these convey the sensation to the upper part of the spinal cord, called the medulla oblongata, from whence it is reflected to the motor nerves—the "*phrenic*"—which induce the respiratory movements.

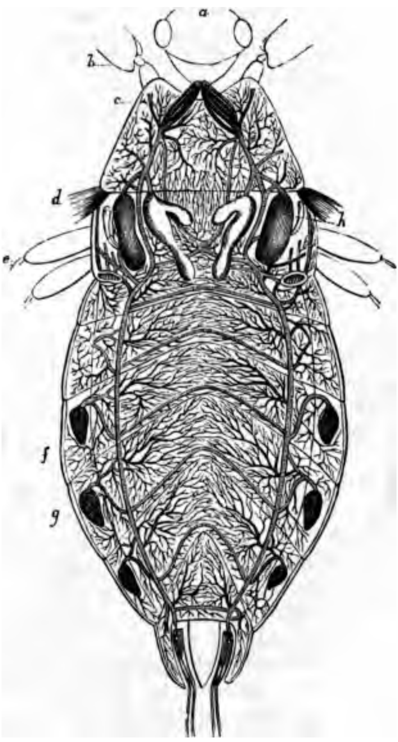
The common phenomena of sobbing, yawning, sighing, &c., are merely modified respiratory movements, influenced by mental or nervous causes, and the sudden dash of cold water on the face or chest will in like manner produce a reflex effect on the respiration. The result of depriving an animal of air is death by asphyxia, consequent upon the accumulation of carbonic acid in the blood, and the distribution of this impure fluid to the heart and brain. If, on the other hand, an undue amount of oxygen is supplied, or if an animal is made to breathe that gas alone, undiluted with nitrogen, the vital activity becomes too great, the animal, so to speak, "lives too fast," and the whole mass of the blood is oxygenated, followed by stagnation of the fluid, death ensuing in about six hours; but whether this result arises from the alterations in the properties of the blood, or from some undue action of the oxygen on the nervous system, is uncertain.

The inhalation of arsenuretted and sulphuretted hydrogen, or the fumes of strong hydrocyanic acid, produces death with great rapidity, evidently from the injurious action of these gases on the nervous system.

Respiration in other Animals.

In the lower animals the respiratory apparatus is much more simple than in man, being adapted to the requirements of the particular types, and modified according to the manner in which the air is destined to act. Thus, in the inhabitants of the water, branchiæ,

or gills, situated externally, take the place of the internal pulmonary structures of terrestial animals; and, in cold-blooded species, the respiratory function is very limited, and, consequently, the vital activity much less than in the warm-blooded, the amount of waste and decomposition of the tissues being unaided by the heat of the body in the former to the extent it is in the latter.



Respiratory Apparatus of an Insect: *a*, the head; *f*, tracheal trunk; *g*, spiracles; *h*, air-sac; *b*, *c*, *d*, legs and wings of insect.

The *Protozoa* possess no definite respiratory system; the whole structure being bathed in aqueous fluid, the oxygen has free access to the various cells composing the body of the animal.

In the *Molluscous* sub-kingdom most of the included animals are adapted for aquatic existence, and provided with gills. The oyster may be cited as an example. The

mantle of this bivalve mollusc is very freely supplied with blood, which is aerated by the water continually admitted between the shells.

In *Articulata*, the annelida and crustacea are provided with a branchial apparatus.

Insects possess a different arrangement; as they are endowed with a great degree of vital activity and muscular energy, causing a corresponding waste of tissue, they require a very free supply of oxygen. To meet this demand, there exists an elaborate system of tubes called "tracheæ," ramifying throughout every part of the frame, communicating with the external air by numerous pores, termed "spiracles," situated at the side in each segment, frequently provided with a grating or network at the entrance, to exclude dust, &c. The spiracles open into short tubes, which communicate with two tracheæ running the whole length of the body, one on each side, from which numerous branches are given off; and, sometimes, air-sacs are attached to the tracheæ near the head. On these canals and air vesicles the minute blood-vessels ramify.

Vertebrate animals, as before stated, differ considerably with regard to their pulmonary apparatus, according to the circulation of warm or cold blood in the system.

Reptiles are provided with lungs of very simple structure, though they are of large size in proportion to the bulk of their bodies. The trachea leads into bronchial tubes, which open directly into two large sacs (occasionally, as in serpents, only one exists), the walls being very thin, and full of depressions. Running down on one side of the sacs, are the pulmonary arteries; on the other the pulmonary veins, communicating with the arteries by a network of capillary vessels. Thus, the capillaries are spread over the sides of the sacs, only one wall of the blood-vessels being in contact with the wall of the air-chambers. The cavity of the chest is not shut off from that of

the abdomen by a diaphragm, so that air enters the pulmonary cavities slowly, and with difficulty, and is not drawn in by any means similar to that provided in the human subject. Some reptiles, indeed, are compelled to swallow the air by a process resembling deglutition.

Though the structure of the lungs is so simple in the lower reptiles, some of the higher species, as the turtle and crocodile, are provided with more complex organs, the pulmonary sacs being separated into numerous cavities by distinct partitions.

Fishes possess gills of complex structure, over which the water is made to flow in a rapid stream. The mouth being first distended, the fluid is forced out through the gills by the action of the muscles surrounding the oral cavity. Thus, the blood circulating through the branchiæ, is submitted pretty freely to the influence of the air, which is but sparingly dissolved in water. In addition to this means of aërating the blood, the air or swim-bladder of some fishes, is supposed to assist in the process. This air-bladder in certain fish is found to communicate with the alimentary canal by a short duct, and as such fishes are frequently observed to rise to the surface to swallow air, it is probable that it passes into the air-bladder, and that the carbonic acid evolved is discharged through the other end of the canal, *per anum*.

The gills of fish consist of four or five bony or cartilaginous arches, from which hang laminæ, composed of minute processes of bone, arranged like fringes, with ramifications of the branchial artery and vein distributed to them; the whole apparatus being contained in a cavity communicating with the mouth, and also opening outward on each side under a bony flap or *operculum*.

In *Birds*, the respiratory apparatus consists of two lungs enclosed in a pleural cavity, communicating with large air-sacs contained in the abdomen. The lungs

are attached to the back of the thoracic cavity, which is shut off from the abdominal by an imperfectly formed diaphragm.

The structure of the pulmonary organs is lobular, each lobule being provided with its own bronchial tube leading direct to the windpipe. In the centre of every lobule is a cavity, surrounded by and opening into a number of sacculi; the walls of these sacculi being composed of meshes of blood-vessels, the air has access to the capillaries on all sides, giving a very free supply of oxygen, rapidly aërating the blood, and thus fulfilling the demand that the vital activity of the animal produces. Birds, more than any other class of beings, require a constant supply of fresh air to their lungs, a very small amount of impurity speedily proving fatal. Even the bones of birds are made subservient in assisting the respiratory function; for they are hollow, and communicate with the lungs; thus, breathing can be carried on through an opening in one of the larger bones, after the trachea has been tied. In aquatic species, however, the cavities in the bones are filled with marrow; and, indeed, in all birds, this is the case whilst they are young.

As no perfect diaphragm exists, the respiratory action is not quite the same as in mammals; the muscles of the chest and abdomen, when contracting, act on the very elastic ribs, driving the sternum inwards, diminish the cavity of the chest, and force out the air; but as soon as the muscles cease to act, the bones spring back to their original position, the cavity is again enlarged, and air rushes in to fill the lungs and air-sacs.

Mammals breathe by means of lungs, the organs being restricted to the cavity of the chest, which is shut off from that of the abdomen by a complete diaphragm. Although the bulk of the respiratory apparatus of mammals is less in comparison with the size of the body than in birds or reptiles, the peculiar *arrangement* of the organs, and their minute sub-

division into numerous air-cells, gives a much larger amount of surface on which the blood is exposed to the action of the atmosphere.

The description of the human lungs already given, will serve for that of mammals generally.

THE PORTAL CIRCULATION.

In addition to the circulation of blood through the lungs, a second and subordinate kind, called the *portal circulation*, is carried on through the liver.

The vessels that bring the blood to the liver are veins, and the vessels that take it away from the organ are also veins; the circulation, therefore, is entirely of a venous character; but, though the blood, after passing through the gland, still remains venous, certain changes occur in its composition.

The portal circulation may be thus described; the veins returning the blood from the spleen, stomach, and intestines, unite and form the *vena portæ;* venous blood is, therefore, carried from these organs to the liver by the portal vein, and that vessel, dividing into the *inter*-lobular veins, distributes the blood to the *intra*-lobular plexuses; the fluid is then collected by the *intra*-lobular veins, which, it will be remembered, unite and form the hepatic veins, and these carry the blood into the ascending vena cava, to mix with the venous current coming from the system at large. Thus it appears that the venous blood from the organs of digestion is carried to the liver by the portal vein, and after circulating through the minute capillary plexuses of the organ, it is collected by the hepatic veins and carried into the general venous circulation.

The blood conveyed by the *hepatic artery* to the liver, for the nourishment of the organ itself, after it has performed this function and become venous, is poured into the vena portæ, forming part of the mass of venous blood from which the bile is eliminated.

Whilst traversing the capillaries of the liver, the portal blood excretes the bile, or rather supplies material to the small cells existing in the meshes of the intra-lobular plexuses, by means of which the bile is elaborated and discharged into the biliary plexuses, to be conveyed to the bile duct.

It is evident that certain changes must take place in the composition of the blood coming to and passing through the liver—that is to say, the hepatic veins will contain a different kind of blood to the portal. Thus, in the hepatic there is less water, albumen, and saline matter, and more grape sugar than in the portal.

The function of the liver may be considered to be two-fold:

1st. To excrete the bile, and thereby eliminate certain hydro-carbons from the blood.

2nd. To produce certain changes in the blood submitted to the action of the hepatic organ, chiefly by forming a peculiar sort of sugar termed liver sugar.

THE HEART, BLOOD-VESSELS, AND CIRCULATION IN THE LOWER ANIMALS.

The lowest types in the animal kingdom possess no true blood-vessels or circulation, all their parts being bathed in the nutritive fluid. The first approach to a circulatory apparatus is the separation of the digestive and alimentary canal from the general cavity of the body, the process of nutrition going on by the transudation of the nutritive fluid through the walls of the canal. In many animals of not quite such low organization, three or four contractile vessels are found without any appearance of a heart, the whole being termed "a water vascular system." Proceeding higher in the animal scale, a heart more or less rudimentary, and true blood-vessels will be found

present. Thus, in many of the higher *Mollusca* and *Articulata*, a tolerably perfect circulatory system exists; in the latter, the heart consists of a single chamber, or ventricle; but in the former an auricle is added. *Vertebrate* animals of all kinds possess a heart and system of blood-vessels of a complex character; amongst the cold-blooded vertebrata, the circulation in reptiles and fishes deserves more especial notice.

Circulation in Fishes.

Fishes are provided with what is termed a branchial heart—that is, the blood proceeds immediately from the heart to the branchiæ, or gills (organs supplying the place of lungs). The heart of a fish has two chambers, one auricle and one ventricle, besides a large dilatation of the principal vein, called the *sinus venosus*. The ventricle is a muscular chamber communicating with a large pouched arterial trunk, the *bulbus arteriosus*, from which four or five vessels arise and ramify in the gills or branchial arches.

Communicating with these vessels, at the other extremity, are the branchial veins, which collect and lead into the large systemic artery of the body, the aorta.

The circulation may be thus described:*—Blood passes from (*a*) the ventricle, into (*b*) the bulbus arteriosus, then into the branchial vessels (*c*), and having been aërated there, passes into the branchial veins (*d*), being carried by them into the aorta (*e*), which distributes it to the body, after which it is collected by the systemic veins, and brought by them into the sinus venosus (*g*), from whence it passes into the auricle (*h*), and then again into the ventricle to be distributed in the same manner. From the branchial arches, two or three small vessels convey pure arterial blood to the head—an arrangement that also exists in crocodiles. Of the blood returned to the heart by the systemic veins (*f*), part is first collected into a trunk that carries it to the kidneys and liver, and having circu-

* See fig., next page.

ated through these glands, is conveyed to the sinus venosus, constituting what is termed the 'portal circulation' in fishes.

Plan of Circulation in Fishes.

- a. Ventricle.
- b. Bulbus arteriosus.
- c. Branchial arteries.
- d. Branchial veins.
- e. Aorta.
- f. Systemic veins forming the vena cava.
- g. Sinus venosus.
- h. Auricle.
- i. Veins returning the blood from the liver, &c.

The *Amphioxus** is provided, besides a heart, with thirty or forty contractile bulbs at the commencement of the branchial arteries, the venous system also having two pulsatile pouches, or hearts developed in its course, one on the vena cava, and one on the vena portæ. The quantity of blood, and size of the blood-vessels, varies greatly with the size of a fish: thus, in the whale, the aorta is about a foot in diameter, and sends forth with great velocity fourteen or fifteen pounds of blood at one gush.

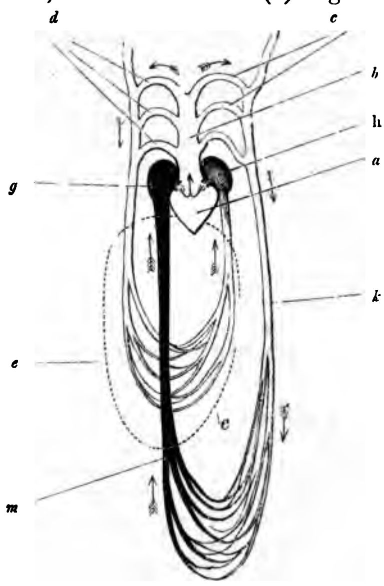
Circulation in Reptiles.

It is evident that animals living on the earth and breathing pure air must have a different arrangement for aërating their blood, as the action of the air will be much more energetic than when acting

* The Amphioxus is an animal of the vertebrate type, in form somewhat resembling a fish, and usually classed as such, but peculiar on account of its imperfect development. It possesses no proper vertebral column, a very rudimentary heart, and no brain; the vertebræ being represented by a cartilaginous cord, the place of the heart supplied by a dilated sinus, the arterial action being assisted by contractile bulbs on the blood-vessels, and the nervous centres represented alone by a spinal cord, without any appearance of a brain.

in water. This increased energy would tend, in combination with other circumstances, to produce a warm-blooded animal; but, as reptiles are destined to lead a life of inactivity, passing a great part of their existence in a state of torpor, and require blood only slightly oxygenated, a peculiar arrangement takes place in their sanguiniferous system.

The hearts of reptiles possess three chambers—a ventricle and two auricles; from the ventricle (a) is given off a large vessel (b), the *truncus arteriosus* dividing into a series of arches right and left, the arches (c) convey the blood to the system at large, the other arches (d) convey the other portion of the blood to the lungs (e), thus only half the blood is aërated. The blood distributed to the system is returned to the right auricle (g), whilst the blood sent to the lungs, after being aërated, is returned to the left auricle (h), both auricles pouring their contents into the ventricle, and this mixture of pure and impure blood is again distributed as before described. Thus it appears



Plan of Circulation in Reptiles.

a. Ventricle.
b, c, d. Arches of truncus arteriosus.
e, e, e. The lungs.
g, h. Right and left auricle.
k. The aorta.
m. The vena cava.

that the blood in the ventricle consists of a mixture of venous blood returned from the tissues, and arterial blood returned from the lungs; the whole mass of the fluid is, therefore, only partly oxygenated, and its distribution produces but a low state of combustion or vital activity.

In some reptiles—the crocodile for example—the heart has a septum in the ventricle, dividing it into two cavities; but in all reptiles a rudimentary partition exists.

In "warm-blooded animals," as birds and mammals, the heart contains four chambers, and a perfect double circulation exists; indeed, so similar is the circulating system to that of man, that no separate description is needed. With regard to the portal circulation, it is only necessary to consider that in the human subject simplified, to apply it to other vertebrate animals.

SECRETION AND EXCRETION.

In different parts of the body, certain organs or glands exist, by means of which various materials are separated from the blood, constituting the processes of secretion and excretion.

Excretion consists of substances already existing in the blood, as carbonic acid, urea, &c., which require to be eliminated from the system; but secretions are elaborated or formed from the blood passing through the glands, and consists frequently of substances which do not pre-exist in the circulating fluid under the same form that they assume in the secretions. Thus, the liver *secretes* the bile, the mammæ the milk, whilst the kidneys *excrete* the urine.

Secretions, therefore, are elaborated from the blood

in glandular structures by the action of the internal cells. Formerly it was maintained that the materials required for the secretion were imbibed by and elaborated in these cells, which remained perfect for a time, and then bursting poured out their contents which formed the secretion; lately it has been asserted that the cells only abstract certain salts, &c., from the serum of the blood, and that the residue forms the secretion.

Certain conditions influence the amount of secretion poured out by the glands; thus, an increased or diminished flow of blood produces a corresponding increase or diminution in the glandular activity. The nervous system may also indirectly or directly affect the process; mental emotion certainly influences many secretions—that of the lachrymal glands for example; or a change in the vascular supply, resulting from nervous influence, may also retard or augment the amount of secretion poured forth.

Excretions are more simple in their chemical composition than secretions, and many of them are remarkable for the facility with which they assume the crystalline form; at the same time, their accumulation in the blood is extremely deleterious, so that they are carried off from the system by the excretory organs as fast as they are generated. Carbon, oxygen, and hydrogen, are the principal elements found in excrementitious substances; and the chief product of animal decay, carbonic acid, is constantly given off by the lungs, ranking as one of the most important eliminated substances. Another very important compound, which passes off through the kidneys in the urine, is urea; the accumulation of the salt in the blood speedily produces profound insensibility (or coma) and death. The exhalation from the lungs and skin, the excretion from the kidneys, and the fæcal matter voided from the intestines, include the chief excrementitious substances discharged from the body.

As a general rule, the substances, whether fluid or

solid, which are poured out by the different glandular structures, may be classed either as secretions or excretions, according to the manner in which they are intended to act on the system, or the effect they have on the various functions. Saliva, gastric juice, milk, &c., are all destined to serve some further purpose in the economy, whilst the urine and fæces are eliminated directly from the body, carrying off matter that would be either useless or injurious to the system.

The bile possesses, in a degree, both the characteristics of secretions and excretions; a certain amount of the hydro-carbon is removed by its production, and at the same time it exerts an influence in the digestive process carried on in the alimentary canal.

THE KIDNEYS.

Situated in the abdominal cavity, one on either side of the spine in the lumbar region, are two similar glands called the kidneys, by means of which the urine is excreted and the refuse nitrogen, lime, sulphur, and phosphorus, eliminated from the system.

The external form of the kidneys or renal bodies is well known. As they are placed in the body, the convex border is turned outwards, and the concave part looks inwards towards the spinal column, the central depression in the concave border being termed the "*hilus renalis.*" The organs are about five inches in length, surrounded by fat, and retained in their position by cellular tissue; the right kidney is placed somewhat lower than the left, which lies almost directly behind the greater end of the stomach; both kidneys being enclosed in a fibrous capsule and surmounted by a small yellowish body of soft spongy texture, called the supra-renal body.

The structure of the kidneys is dense and fragile, consisting of tubes and blood-vessels. If a vertical

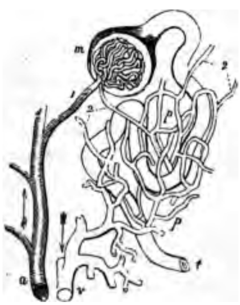
section is made, the external portion of the organ termed the "cortical" part, will be found to be composed of blood-vessels and convolutions of small tubes called the *uriniferous tubuli*, with numerous small, round bodies (the malpighian corpuscles) interspersed. The internal part of the gland will be seen to consist of bundles of straight uriniferous tubuli, arranged into pyramidal masses, called the *cones* of the kidney. In the middle of the organ at the hilus, is an irregular cavity termed the *pelvis* of the kidney, into which the cones project. Leading from this cavity is a tube—the *ureter*—which runs down the posterior wall of the abdomen, and opens into the bladder. The ureter is about the size of a goose-quill, nearly eighteen inches in length, being larger above than below, and composed of an external fibrous and an internal mucous coat, communicating at one end with the pelvis of the kidney and opening by the other into the urinary bladder. The "*cones*" of the kidneys, therefore, are composed of straight uriniferous tubes, bound up together into pyramidal masses, which project irregularly into the pelvis of the kidney, leaving small pouches between them called the *infundibula*. The ends of the uriniferous tubuli composing the cones, open at the extremity or papilla of each cone, communicating with the infundibula, and thus with the pelvis of the kidney, which is in fact the upper part of the ureter enlarged and inserted in the

Section of the Kidney: 1, the supra-renal body; 2, vascular portion; 3, 3, tubular portion; 4, 4, papillæ; 5, 5, 5, infundibula; the space in the centre is called the "pelvis" of the kidney; 6, 7, ureter.

hilus renalis. Covering the projecting apices of the cones, are cup-like pouches of mucous membrane termed the *calyces.*

The urinary tubuli are about $\frac{1}{100}$th of an inch in diameter, formed of simple membrane, lined throughout with nucleated cells, arranged as an epithelial covering. At one extremity, the tubes are open, at the other they enter the cortical substance or external part of the organ, become convoluted or twisted, and end in little round bodies called the malpighian corpuscles.

VESSELS.—Entering the kidney at the hilus is a large artery—the renal artery—derived from the abdominal aorta, and leaving the gland in the same situation, is a large vein, the renal vein, which opens into the inferior cava. The minute subdivision of these two vessels form the greater part of the cortical portion of the renal organ. The minute distribution of the vessels, however, is very peculiar. The renal artery divides into numerous branches; one of which, being traced, will be found to enter a small capsule, where it breaks up into a number of minute vessels, forming a vascular ball. Leading from this ball is another vessel which is termed the *efferent* vessel, and several of these efferent vessels meeting, form round the uriniferous tubes a plexus of capillaries, from which the renal vein arises. The vascular mass formed by the branch from the renal artery, and provided with an efferent vessel, is in contact with the terminal pouch of one of the uriniferous tubuli; the



Plan of the Renal Circulation: *a*, artery, branch of the renal; *m*, malpighian body; *t*, uriniferous tube; *v*. branch of the renal vein; *p*, *plexus* ramifying upon the tube; *2, 2, efferent vessels.*

whole being enclosed in a capsule, constituting a *malpighian corpuscle.*

The Function of the Kidney is purely excretory, and destined to remove from the system a large amount of water with certain salts in solution.

The watery part of the urine is separated from the blood in the malpighian corpuscles; but the solid constituents are separated by means of the cells throughout the whole extent of the urinary tubes which is embraced by the venous plexuses.

When excreted, the urine passes into the pelvis of the kidney, and thence down the ureter into the bladder, any regurgitation of the fluid being prevented by the manner in which the ureters enter the walls of that organ, namely, by passing obliquely for about three quarters of an inch between the muscular and mucous coats, and then abruptly penetrating the mucous lining and opening into the interior.

The urine collects in the bladder, till the distension of its walls produces a sufficient sensation to induce an effort of the will to procure the expulsion of the fluid.

The Kidneys of other Animals.

Renal organs are but little developed amongst Invertebrata, and always present a tubular structure. Thus, in *insects*, the kidneys consist of two groups of tubuli closed at one extremity, and opening by the other into the pouch or cloaca at the end of the intestinal canal.

Molluscous animals, however, possess renal bodies of a follicular character; but it is not till we ascend to the higher sub-kingdom, the *vertebrata*, that any great advance of development will be found.

Amongst *Vertebrata*, the urinary organs of *fishes* is the most simple, though the renal bodies are of large size.

centre or axis, independent ganglia or masses of nervous substance, are found scattered in various parts of the frame; and these ganglia and the nerves connected with them, comprise another portion of the nervous system, termed the sympathetic or ganglionic system. From the cerebro-spinal axis numerous cords or nerves extend to the muscles and other organs, forming the medium of connection between the distant parts of the body and the nervous centre. But the function is not the same in all the nervous cords, which are divisible into two classes, the *afferent* or *excitor*, and the *efferent* or *motor;* the former convey impressions from the external parts *to* the brain; the latter conduct the nervous force *from* the brain to the part where the impression was received. Usually, however, both the afferent and efferent fibres are bound up together into one nervous cord, so that they cannot be separated or distinguished, forming as it were a single nerve, with a double function.

The functions of the nervous system may be carried on without the participation of the mind, by what is termed *reflex* or *excito-motor* action; that is, an impression may be conveyed along an afferent nerve to the brain, and there produce a certain effect, which is transmitted to the efferent nerve, through which the part supplied by these nerves is put in motion. The involuntary continuance of the action of breathing depends on this excito-motor principle. The sympathetic ganglia are also connected with nerves, which, for the most part, are distributed to the viscera, and are independent of the influence of the will; on the other hand, the cerebro-spinal nerves are chiefly distributed to the skin, muscles, and organs of special sense, as the eye, ear, &c., being to greater or less extent under the control of the will.

ANATOMY OF THE BRAIN AND ITS MEMBRANES.

Enclosed within the cavity of the cranium is that portion of the nervous system termed the brain. It fits the cranial cavity very closely; its form, therefore, in a general way, is represented by that of the skull. Covering the brain are three membranes—the dura mater, pia mater, and arachnoid.

The *dura mater*, the most external, is a strong fibrous membrane adhering to the surface of the bones of the cranium, and sending processes down between different parts of the brain, leaving channels for the flow of venous blood in some of the membranous folds. In the young subject the dura mater is very vascular, serving as an internal periosteum; but in the adult it is less freely supplied with blood, and serves chiefly to protect the encephalon or parts within the head.

The *arachnoid*, the second membrane, lies under the dura mater; it is very thin and delicate, of a serous character, and like all serous membranes, is a closed sac, being reflected from the under surface of the dura mater, which it lines, on to the brain and spinal cord.

Neither vessels nor nerves have been traced in this delicate membrane, its function, probably, being purely mechanical, permitting a certain degree of movement of the encephalon without an undue amount of friction.

The *pia mater*, the internal of the three membranes, covering the whole surface of the brain, and dipping into all the fissures and sulci on its surface, is a highly vascular structure, consisting of numerous blood-vessels held together by fibro-cellular tissue.

The pia mater derives its supply of blood from the carotid arteries, and affords nourishment to the substance of the brain.

The membranes covering the brain having been re-

moved, the external surface of the organ comes into view, presenting numerous folds or convolutions of a slate-gray colour, these convolutions being separated from each other by shallow fissures, which, in certain situations, extend to some depth in the brain substance.

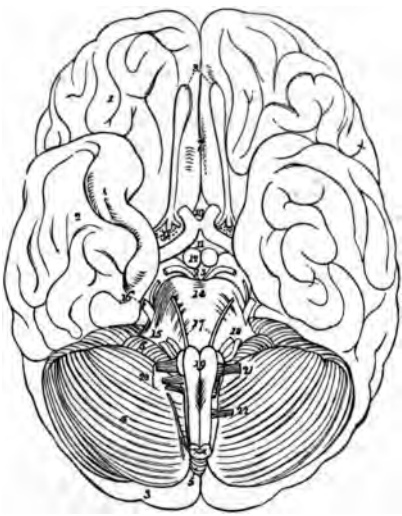
Two principal divisions exist in the organ, the upper and anterior part being termed the *cerebrum*, the lower and posterior portion the *cerebellum*.

The *cerebrum* is the larger part of the brain, making up about six sevenths of the whole bulk. It is divided into two hemispheres by a deep, longitudinal fissure running from the front to the back of the head; and the under surface is divided by fissures into three lobes, anterior, middle, and posterior. At the bottom of the longitudinal fissure is a thick layer of medullary fibres, passing transversely between the two hemispheres, constituting the "great commissure," or *corpus callosum*. If the upper part of the cerebrum is removed down to the corpus callosum, the interior of the brain will be found to consist of white fibres, and two irregular cavities will be laid open, called the "*lateral ventricles*." Bounding these cavities are various projections of brain substance, and in other parts of the organ two additional cavities exist, termed the third and fourth ventricles. The interior of these small chambers is lined by reflected processes of the arachnoid.

The *cerebellum* forms only one seventh of the whole brain, and is situated beneath the posterior lobes of the cerebrum, from which it is separated by a process of the dura mater, called the tentorium. Like the cerebrum, the cerebellum is divided into two lobes by a fissure, being connected also by commissures; the inferior termed the *pons Varolii*, and the superior the *vermiform process*. The external surface consists of gray matter; but, instead of taking the form of convolutions, it is arranged in *parallel* laminæ, separated by fissures.

If a vertical incision is made into the cerebellum, the interior presents the white substance and a peculiar arrangement of fibres, resembling the branches and leaves of a tree, called the *arbor vitæ*.

At the *base of the brain* are many important structures; at the anterior part, running directly forwards,



The Under Surface of the Brain: 1, anterior lobe of cerebrum; 2, middle lobe; 3, posterior lobe, almost hidden by (4) the cerebellum; 7, longitudinal fissure; 8, 9, olfactory nerves; 10, commissure of optic nerves; 11, 12, 13, space between the optic tracts and crura cerebri; 14, pons Varolii; 15, crus cerebelli; 16, 17, the fifth and sixth pair of nerves; 18, 20, 21, the seventh, eighth, and ninth pairs; 19, medulla oblongata: 22, first spinal nerve.

are two nerves, the olfactory; just behind these, in the centre of the space between the two middle lobes of the cerebrum, is the origin of the two *optic nerves*, forming the *optic commissure;* and a little further back is a large, arched prominence (composed of a

broad band of white fibres), called the *pons Varolii*. Joining this posteriorly, is the upper part of the spinal cord, termed the *medulla oblongata*, and in front and on either side of the pons several small nerves issue forth.

THE SPINAL CORD.

Extending from the pons Varolii to the lumbar region, enclosed in the spinal canal, is a long cord of nerve substance, forming the remaining portion of the cerebro-spinal axis, and termed the *spinal cord* or *marrow*. The upper portion is enlarged, and receives the name of the *medulla oblongata*. At the lower extremity the cord actually terminates about the *second* lumbar vertebra, part of the structure only, in the form of white bands, being continued farther down the canal, constituting what is termed the *cauda equina*.

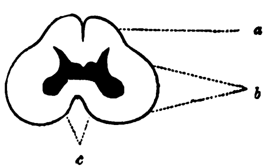
The form of the spinal cord is a flattened cylinder, presenting a fissure on its anterior and posterior surface. These fissures extend the whole length of the cord; and, covering it externally, are three membranes, continuous with those of the brain, and named in the same manner dura mater, arachnoid, and pia mater.

The *dura mater of the cord* resembles that of the brain as regards structure, but it is only loosely connected with the walls of the spinal canal.

The *arachnoid* is like that of the brain, and embraces the cord very loosely, leaving a space between the two structures, which is filled with fluid called the subarachnoidean fluid.

The *pia mater* of the cord differs from that of the brain, though it is continuous with it; for, instead of being a delicate, vascular membrane, it is strong and fibrous, containing very few blood-vessels. It extends into the anterior and posterior fissures of the cord, and sends off fibrous processes, called the "ligamenta *dentata*."

The *medulla oblongata*, or upper part of the spinal cord, is somewhat conical in shape, and about an inch in length; two fissures, an anterior and a posterior, run longitudinally on the surface, dividing it into two symmetrical lateral columns, which are again divided into three smaller portions by slighter fissures. At its lower extremity the medulla oblongata joins the more contracted part of the spinal cord which passes down the spinal canal.



Section of the Spinal Cord.
a. Posterior column.
b. Lateral columns.
c. Anterior columns.

If a transverse section of the *spinal cord* is made, the posterior longitudinal fissure will be found to be very narrow, extending deeply into the substance, but the anterior longitudinal fissure will be seen to be wider, extending into the cord to about one third of its diameter.

These two fissures divide the cord into two great lateral columns, which are connected by a commissure of medullary substance. Each column is again divided into three lesser columns by slighter depressions.

The external portion of the spinal cord is white and the internal gray, each lateral column having its central gray portion; and the same arrangement exists in the commissure.

The form of the gray matter situated in either lateral column is that of a half or new moon, the convex surfaces being turned towards the commissure, so that the convexity of both portions of gray matter look towards each other, being united by a transverse band. At certain intervals down the spinal cord spring the spinal nerves; and the horns of the moon-shaped gray matter extend towards the spot from which the nerves arise. The anterior horn ends before it reaches the surface of the cord, but the posterior, which is the smaller, is continued by a fine filament to the surface.

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The internal gray substance continues down the cord to the second lumbar vertebra, where it terminates, the white substance alone being prolonged, in the form of numerous white bands or separate fibres, extending as far as the sacral part of the spinal canal. This termination of the cord has received the name of the *cauda equina*, and at this part of the canal the investing membranes are stronger than at the upper portion of the structure.

THE NERVES.

The nerves are bands or cords arising in the brain and spinal cord, and distributed to various parts of the system. Those which arise within the cranium from the brain or medulla oblongata are termed *cranial* nerves, and those which pass from the spinal cord are called *spinal* nerves.

The *cranial nerves* consist of eighteen nerves, arranged in nine pairs, a similar nerve arising on either side of the brain; they may be classed as follows:

Arising from the brain and pons Varolii.	1. Olfactory nerves,	distributed	to the lining membrane of the nose.
	2. Optic nerves	"	to the eyeball.
	3. Motores oculorum	"	to the muscles of the eye.
	4. Trochleares	"	to the muscles of the eye.
	5. Trifacial	"	to the face and tongue.
	6. Abducentes	"	to the muscles of the eye.
	7. Portio dura	"	to the face.
	7. Portio mollis	"	to the ear.

Arising from the medulla oblongata.	8.	Glosso - pharyngeal,	distri-buted.	to the tongue and throat.
		Vagus	,,	to the lungs, larynx, and stomach.
		Spinal accessory	,,	to the muscles of the neck and back.
	9.	Hypoglossal	,,	to the muscles of the tongue.

Though the cranial nerves have special names, yet they are frequently mentioned according to the position in which they stand respecting the others; thus, the olfactory nerves are termed the first pair, because they arise farthest forward in the brain, and so on for the remainder.

The cranial nerves may be again divided into those that are either motor, sensory, or compound; thus, the first and second nerves are nerves of sensation ; the third, fourth, sixth, and ninth, purely nerves of motion ; and the fifth, seventh, and eighth are endowed with the combined functions of motion and sensation.

The *first*, or olfactory nerves, are distributed to the membrane lining the nasal organ, endowing it with the sense of smell.

The *second*, or optic nerves, are two round, white cords, arising from a common commissure, and entering the posterior part of the eyeballs, where an expansion of the internal gray matter forms the retina or nerve on which the visual impressions are received.

The *third*, *fourth*, and *sixth* nerves are distributed to the muscles of the eyeball, giving the power of directing the organ towards any point above, below, or laterally.

The *fifth* is a complex nerve, endowed with a compound function, and divided into three chief trunks, called the superior and inferior maxillary and ophthalmic nerves. The inferior maxillary gives off a branch called the gustatory, which is distributed to

the tongue, giving it the sense of taste; but the ramifications of the other two branches are distributed to the skin of the face.

The *seventh* nerve is also divided, but only into two parts, the facial and auditory; the former supplies the muscles of the face, and the latter is distributed to the interior of the ear.

The *eighth* nerve arises from the medulla oblongata, and consists of three portions, the glosso-pharyngeal, the vagus, and spinal accessory, the last so called because it arises lower down from the cord, and only partly joins the rest of the nerve. The most important part of the eighth nerve is the vagus, or pneumogastric, which, passing down the neck behind the great blood-vessels, runs to the back of the lungs, and continuing downwards through the thoracic cavity, perforating the diaphragm, is finally distributed to the stomach. In the course of the nerve numerous branches are given off, the principal being those to the larynx, heart, œsophagus, and lungs.

The *ninth* nerve also arises from the medulla, and is distributed chiefly to the muscles of the tongue, sending off communicating branches to the gustatory and vagus.

All the above-mentioned nerves issue from the interior of the skull, through holes or foramina in the bones.

The spinal nerves are arranged in thirty-one pairs, a similar nerve arising on either side from the lateral columns of the spinal cord by two *roots*, an anterior and a posterior, the latter being the larger, and having a ganglion situated on it. Between the roots passes a process of the pia mater of the cord, called the *ligamentum dentatum*, before mentioned. The two roots, after being separated for a short distance, meet and form a spinal nerve, which issues from the spinal canal through a notch between two adjacent vertebræ. The anterior is termed the motor root and the posterior the sensory, the reason of which will be noticed in describing the functions of the nervous system.

After leaving the canal the nerves divide into

branches, and in certain regions form plexuses by their union with other branches and from these fresh nerves are given off. As they approach their destination the trunks break up into numerous smaller branches, which are distributed to the various organs, as the muscles, skin, &c.

The spinal nerves are arranged in pairs, according to the situation of their origin; thus, there are—

8	pairs	of cervical	nerves.
12	„	dorsal	„
5	„	lumbar	„
6	„	sacral	„

Structure of the Cerebro-Spinal Axis and Nerves.

On examining the brain by making sections of its structure, it is found to be made up of an external gray and an internal white matter; the former being apparently homogeneous, the latter having a somewhat fibrous appearance.

When examined closely, the *gray substance* is found to consist of a finely granular matter, traversed by capillary vessels in all directions, and studded with numerous nucleated cells of irregular shape, many with processes jutting off, giving them a stellate or caudate form. In the interior of these cells is granular matter and pigment or colouring material, which produces the gray tint of the whole mass.

The *white* or *internal substance* consists of tubes, about the $\frac{1}{5000}$th to the $\frac{1}{10,000}$th of an inch in diameter. If these white fibres are carefully examined under the microscope their structure will be found to be somewhat complex; they are perfect cylinders, invested and supported by a delicate membrane, the contained nervous substance being composed of two different materials; externally is a tube of white, and internally a column or axis of gray matter.

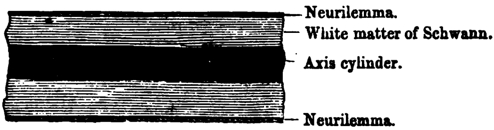
Though the white or tubular brain substance is more firm and consistent than the gray, still, it is soft and yielding, on account of the large amount of water

that enters into its composition. The comparative chemical analysis is as follows:

	White substance.		Gray.
Water	73	......	85
Albumen	10	......	8
Fatty matter	14	......	5
Earthy phosphates, osmazome, &c.	3	......	2
	100		100

In the *spinal cord* the arrangement of white and gray matter is reversed, the white being external and the gray internal; but the fibres and cells present in the cord resemble those in the brain, except that the white fibres of the cord are rather larger in diameter, and run longitudinally with respect to its axis, that is, they pass upwards towards the brain.

The *nerves* are, in like manner, made up of fibres of gray and white matter, the internal gray substance being called the *axis cylinder*, and the external white matter being termed the "white matter of Schwann."



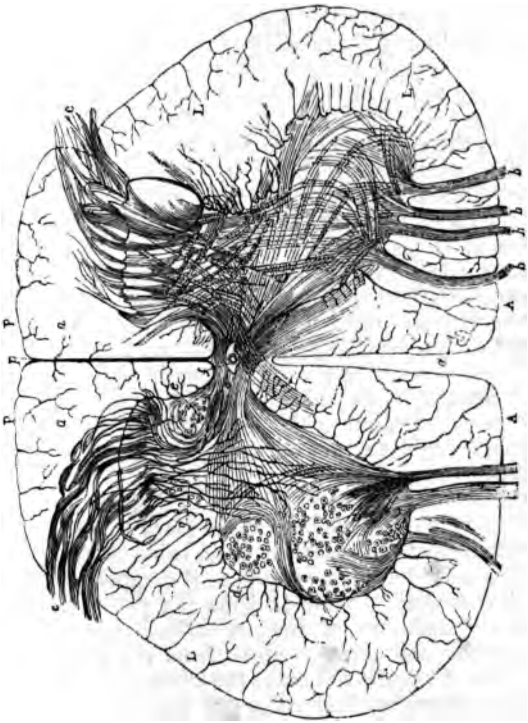
Section of a Nerve-fibre.

Covering the exterior of the nervous fibres is a delicate membrane or neurilemma, analogous to the sarcolemma, enclosing the ultimate fibres of muscular structure. The termination of the nerves is varied, and will be described hereafter.


Origin of Nerves by two roots from the Spinal Cord.

The spinal nerves join the cord by two roots, an anterior and posterior, the former entering the anterior part, and the latter joining the posterior portion of the cord.

The white fibres of the nerves entering the cord are continued upwards and lost in its substance; pro-



Section of Spinal Cord, magnified: A, A, anterior columns; P, P, posterior columns; L, L, lateral columns; *a*, anterior fissure; *p*, posterior fissure; *b*, *b*, *b*, anterior roots of nerves; *c*, *c*, posterior roots of nerves; *d*, *e*, *g*, gray matter; *f*, a small canal in the centre of the cord.

bably they pass up to the white internal portion of the brain. The gray matter of the nerves passes from the interior of the nerves and joins that of the cord, which, though made up of cells, contains gray fibres

also, and from a close examination it appears that some of the fibres coming from the roots of the nerves traverse the commissure of the cord and blend with the gray matter in the opposite column, this crossing and blending of fibres being termed "a decussation."

The ultimate termination, however, of the fibres entering the cord is very doubtful, and in all probability some of them run up to the brain, whilst others end in the structure of the cord itself.

The *medulla oblongata*, or upper part of the spinal cord, presents on section a decussation and crossing of the fibres, which are prolonged on into the cerebral lobes at the base of the brain. Thus it appears that either side of the cord is in communication by its fibres with the opposite side of the brain; that is, the fibres from the right column of the cord go to the left lobes of the brain, and *vice versâ*, so that the fibres of a nerve entering the lower part of the spinal cord, and running up its substance to the brain, would be in communication with the opposite side of the cerebral organ to that on which the nerve originally entered the cord.

In many diseases and injuries to the brain paralysis of the muscles of the body takes place on the side opposite to that on which the brain is affected.

The anterior part, or rather the upper extremity, of the medulla oblongata joins the pons Varolii or great commissure of the *cerebellum*, and through this body the *anterior* fibres from the medulla oblongata are continued on to the lobes of the *cerebrum*. These fibres, as they enter the cerebral lobes, take the name of *crura cerebri*, each of the crura being divided into two tracts, conveying *motor* and *sensory* fibres respectively. The fibres from the *posterior* tracts of the medulla are chiefly connected with the cerebellum.

Some difficulty will be found in understanding the course of the fibres from the medulla to the lobes of the cerebrum and cerebellum, but the following de-

scription may serve to give some insight into the general arrangement.

It will be remembered that the cerebrum is remarkable for the arrangement of its vesicular or gray matter, which is placed on the external surface, covering in the white fibres. On either side, at the base of the cerebral hemispheres, are two large ganglionic masses, called the *thalami optici* and *corpora striata*. They contain a large amount of gray matter, and may be considered not only as appendages to the cerebrum, but also as independent ganglionic centres. Now, as already noticed, a sensory and motor tract may be distinguished in the medulla oblongata and crura cerebri; the sensory tract may be traced upwards till it is lost in the structure of the thalami optici, and the motor fibres may be traced to the corpora striata. Moreover, the optic and auditory nerves have a distinct connection with the thalami optici, and they may, therefore, be regarded as the focus of sensory nerves, and the corpora striata as the principal motor centre. Between the thalami optici runs a commissure, called the *anterior commissure;* and between the corpus striatum, on either side, there is also a commissure. Thus, the ganglionic masses are connected with each other; that is, the two optic thalami are united, and also the two striated bodies. Besides their connection with the fibres of the medulla oblongata running to them through the crura cerebri, they are also in communication with the external gray matter on the surface of the brain, by means of fibres which extend outwards in all directions. Thus, these ganglionic centres are connected, not only with the spinal cord, but also with the external gray convolutions of the cerebral mass.

Termination of the Nerves.

The nerves distributed to the different textures of the body, after dividing into minute branches, terminate either by forming loops or by free extremities.

The termination in loops is most common. In muscular structure, in papillæ, and in the skin, this mode of ending is observed, but in some situations the termination by free extremities may be seen. On the nerve-fibres passing through the fat to the skin of the hand and foot, and also on the nerves of the solar plexus in the abdomen, small oval corpuscles have been found, about $\frac{1}{10}$th of an inch in length and half that in breadth. On examining any one of these Pacinian corpuscles, as they are called, it exhibits the terminal fibres of the nerve, surrounded by several delicate layers of fibrous membrane, arranged like the coats of an onion. In the central cavity of the corpuscle and between the fibrous layers is an albuminous fluid; and floating in the internal cavity is the end of the nerve-fibre, terminating in one or more branches by a sort of bulb on each terminal branch. As the nerve enters the corpuscle, the neurilemma and then the white matter ceases, the internal gray structure alone being continued on.

The function of the Pacinian corpuscles is quite unknown, and no very probable theory has yet appeared respecting their use or action.

There still remains another mode of termination of nerve-fibres, namely, by free extremities; this method is alone observed in the fungiform papillæ of the tongue, where the white matter seems to cease, whilst the gray substance of the nerve-fibres is continued up to the summit of the papillæ.

Of the Action and Function of the Nervous System.

The brain and spinal cord are the organs in which *the nerve* force is generated; the former may be con-

sidered as one large ganglion, the latter may be regarded as several ganglia, corresponding in number with the vertebræ, so that each portion of the cord opposite or enclosed in any one vertebra may be considered as a separate ganglionic centre to the pair of nerves springing from that spot.

The *vesicular* or cell-structure in the gray matter is that in which the *nerve force* is generated, and the gray matter is that portion of the nervous substance by which this force is conducted along the nerve-fibres, the white matter being, probably, an insulating substance, sheathing the gray in its course, and preventing any diffusion of the nervous current. Considerable difference of opinion exists respecting the conducting and insulating power of the white and gray matter. Some physiologists deny the insulating power of the white matter, and look upon the gray and white substances as afferent and efferent fibres. Moreover, some deny the presence of a distinct gray axis cylinder in the nerves, asserting that during life the whole nerve substance in the sheath of neurilemma is homogeneous, and that the cooling of the fibres, or some post-mortem change, gives the appearance of a central axis of gray matter. Others consider that the nerve-fibres are *hollow* tubes, and that during life a central cavity exists; but that as soon as death takes place the nerve-fibres, as it were, collapse, and thus form a flattened band. But though these opinions are maintained, there can be but little doubt that a central axis of gray matter does exist; whether existing during life as a hollow tube enclosed in another tube of white matter, or whether as a central axis surrounded by a tube of white matter, is of little importance. The function of the gray matter seems to be connected with the generation and transmission of nerve force, and the white with the power of insulation; for though some nerves, especially those of the skin and muscles, end in loops, so that nowhere does the gray matter come into actual contact with the muscle or

skin, yet these loops may not be the absolute termination of the nerve-fibres; or the nerve force may possibly act through the white matter at that particular part. In some nerves that end in free extremities, however, the white matter is laid aside, and the gray alone continued on at their termination, as seen in some of the nerves distributed to the papillæ of the tongue, and thus the gray matter would in this case be in absolute contact with the structure to which the nerves were distributed. If, then, it is true that the white matter acts as an insulating covering to the gray, the structure and function of a nerve would not be unlike that of a telegraph wire, the two different nerve materials being represented by the copper and gutta percha. The function of the *roots* of the spinal nerves, however, is more certain. Sir C. Bell found that when the anterior root of a nerve was divided the part supplied by that nerve lost all power of motion, and when the posterior root was severed, the sensibility of the part was destroyed, though the motive power remained intact. Thus we may regard the anterior root as the motor and the posterior as the sensory part of the spinal nerves where they join the spinal cord.

Generation of Nerve Force.

The production of nerve force requires a free supply of pure oxygenated blood; and the ill effect of deficient circulation, or the flow of impure blood through the brain, is speedily manifest by the loss of sensation and motion. Anything, therefore, that retards or arrests the supply of blood to the capillaries of the brain retards or destroys nervous action. Cold produces its benumbing effect on the nervous system from this cause.

During the generation of nerve force some reaction takes place between the elements of nerve-tissue and *certain* materials in the blood, the principal being, in

all probability, the oxygen contained in that fluid. The very production of nervous power by the action of this gas on the nervous structure disintegrates the tissue, a result which is clearly shown by the large amount of phosphates in the urine after any unusual mental exertion or excitement; for as no other soft tissue, except that of the brain, contains much phosphatic substance, the waste of the nervous structure must be that to which the presence of the phosphatic salts in the urine is due.

Whatever the nerve force or fluid may be, it resembles, if it is not identical with, the electric fluid, obeying laws similar to those which govern the action of that fluid, and exhibiting phenomena analogous to those produced by electrical action. Nay, more; an electric current passing along an efferent nerve will excite muscular contractions in the part supplied by that nerve, and an electric current passing along only a short portion of a nerve will excite or generate nerve force in the remaining portion, and the exertion of nerve force in the electric fish generates electricity.

Thus it would appear that if the nerve force is not identical with the electric, it bears much the same relation to it that magnetism does to electricity, for in like manner electrical action can produce magnetic, and magnetic power can produce electrical action.

From experiments made on animals recently killed, it has been found that electricity excites muscular action; but after the current has been passed along the nerve for some time, the effect ceases. Besides this influence, that of heat, light, and chemical action, produce or excite nerve force.

Reflex action.—One of the principal functions with which the spinal cord is connected is that of reflex action. The spinal nerves, as before stated, arise by two roots, the posterior being provided with a ganglion. If the anterior root is divided, motion is lost to the part

supplied by the nerve; and if the posterior root is cut, sensation ceases. The anterior, therefore, is termed the "motor" root, and the posterior the "sensory." When the extremity of a nerve is acted on or influenced by some external impression, the afferent portion of the nerve conveys the impression to the brain, and the efferent part refers it to the spot where the impression was received, or sets in motion the muscles to which the nerve is distributed. Thus it may be inferred that the impression on the terminal portion of the nerve produces a certain change in, or effect on, the nerve substance, which, being transmitted to the brain or cord, generates there a certain force, which, in its turn, acts on the efferent fibres of the nerves, and produces a result termed the reflex action. What the exact nature of the changes is, which take place in this action, is as yet unknown. The whole process may go on without the intervention of the mind and independent of the control of the will, the entire action being automatic, as is the case in convulsions and spasmodic diseases generally. The best example of continued excito-motor or reflex action is that which gives rise to the respiratory action, and has been mentioned in the description of the respiratory function.

The functions of the Cerebellum.—It is evident, from the extent of gray substance in the cerebellum, that it must be connected with very important functions. Through the great commissure of this organ, the pons Varolii, pass the motor and sensory fibres from the spinal cord, en route to the thalami optici and corpora striata; and as these fibres traverse the pons they send off some filaments which connect them with the cerebellum.

It has been found that if the cerebellum of one of the lower animals is gradually sliced away, or even altogether removed, very slight disturbance of the actions directly necessary to life takes place, but the power of walking, flying, leaping, or even of preserving

a balance, is entirely lost; now, as these varied actions require a combined action of several muscles under the direct control of the will, the cerebellum may be considered to combine muscular movements which are not of a simple reflex character. When only one side of the organ is removed from an animal, it exhibits a tendency to turn round on an axis, and in cases of disease of the human cerebellum an unsteady gait is often observed. In all probability, therefore, the cerebellum is a regulator and co-ordinator of muscular action; besides which, it is also stated to have some relation to the generative functions.

The functions of the Cerebrum.—The cerebrum is doubtless the seat of sensation, volition, and the intellectual faculties or mind, and through its instrumentality the process of *thought* and exercise of the *will* is carried on.

The external vesicular matter is called into activity by impressions conveyed to it by the fibres extending between it and the ganglia at the base of the brain, the thalami optici, and corpora striata; but the action excited by this transmission of external impressions, is regulated and directed by that power of the mind termed the *will*. The action of the cerebrum, therefore, is governed by this influence, for, without such intervention, its functions would be merely reflex. The power of the cerebrum, however, depends entirely on the intermediation of the spinal axis, for no motor fibres issue directly from the cerebrum itself, and if its connection with the medulla oblongata is cut off all motor action ceases.

A free supply of blood is necessary for the continuance of cerebral action, defective nutrition impairing the functions of the brain, which may be deranged in a great degree without any lesion of cerebral substance.

The ganglionic masses, the thalami optici, and corpora striata, may be regarded as the true sensorium, for in the lower animals they are frequently found

greatly developed, whilst the cerebral hemispheres are comparatively small.

Numerous experiments have been made to determine the exact nature of the functions performed by the thalami optici and corpora striata, but no very definite results have been arrived at, partly on account of the difficulty experienced in making any experimental investigation, as it is almost impossible to isolate these ganglia.

The power of voluntary motion seems to depend on the presence of the thalami optici, for when these have been removed from the brain of an animal, the power of movement is lost. On the other hand, the corpora striata seem to govern the function of sensation, for when these ganglia are removed from an animal, it falls into a profound state of coma.

With regard to the crura cerebri, it is found that if they are completely divided, total loss of sensation and motion is the result. The *will*, therefore, may be exercised without any effect being produced, if the crura are divided. This is seen in cases of paralysis, where the desire to move is present, but the power is wanting.

Briefly, then, the spinal cord may be regarded as the centre of reflex action; the cerebellum as the organ which combines or co-ordinates muscular movements; and the cerebrum as the seat of the intellect, will, emotions, and sensations, directing and regulating the action of the cord and cerebellum.

The Sympathetic System.

The sympathetic system consists of numerous ganglia, with nerves attached, situated in various parts of the body, and connected by nervous filaments with the nerves of the cerebro-spinal system.

The sympathetic system may be regarded as capable of arrangement under the following heads:—First. A

chain of ganglia situated on either side of the spinal column, connected with each other and with the spinal nerves. Second. Three large plexuses distributed to the heart and abdominal viscera, termed the *cardiac*, *hypogastric*, and *solar*.

The structure of sympathetic ganglia is similar to that of the vesicular gray matter already described, and the nerves from these centres are chiefly distributed to the viscera. The functions of the system relate to the organic or vegetative part of the economy; and as the cerebro-spinal system and sympathetic are connected by branches of nerves, the two systems react on each other, but the sympathetic is in no way under the control of the will, though the emotions influence its action.

The Nervous System in the Lower Animals.

Many of the lowest forms of animals present no trace of a nervous system; amongst the various *Protozoa*, and the *Hydrozoa*, and *Actinozoa*, no nervous centres or even nerve-fibres can be distinguished throughout the body, nor is it till we arrive at the *Echinodermata* that the existence of a nervous system is manifest; here a ring of nerve-fibres is found to surround the mouth, and in the star-fish three nerve-filaments are distributed to each ray.

In the *Molluscous* classes numerous separate ganglionic masses are distributed throughout the body, giving off cords of nerve matter to various parts of the system. One ganglion is found for each important organ, but three principal masses are usually present, namely, two ganglia on the sides of the œsophagus, giving off two cords to the mouth and appendages; next, a single ganglion situated beneath the œsophagus, supplying a nerve to the feet or foot; and, lastly, a single ganglion situated at the posterior part of the body. These ganglia receive respectively the names

cephalic, pedal, and parieto-splanchnic, the whole of them being sensory centres.

In the *Articulata* the plan on which the nervous system is developed is very uniform. It consists usually of a double cord running down the *ventral* surface of the body, studded with ganglia at intervals, a pair of ganglia corresponding to each segment. Near the head, the two filaments of the cord diverge and embrace the œsophagus, above which a pair of ganglia (sometimes only one) are situated; into these supra-œsophageal ganglia the nerve-filaments run, connecting them with the rest of the nervous chain; moreover, the nerves from the eyes join the same ganglia. Though almost all articulate animals possess this arrangement of a double gangliated cord, we find in the lower forms of worms two simple cords, without any ganglionic masses present.

When the various segments of the animal are very similar, the size and appearance of the different ganglia is also found to be much alike, but in all cases the supra-œsophageal ganglion may be regarded as the rudimentary brain.

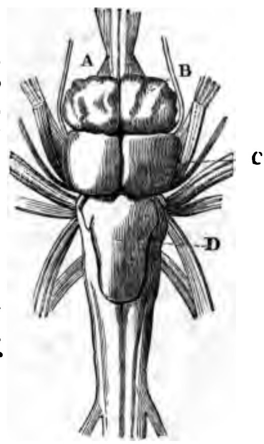
Insects.—In the nervous system of these creatures a tendency is shown towards the development of larger and more numerous ganglionic masses in or near the head. The same arrangement of a gangliated cord still pertains, and the principal ganglia may be considered as so many *motor* centres.

Vertebrata.—A great advance in the complexity of arrangement and structure of the nervous system is exhibited in all vertebrate animals as compared with invertebrate.

In the sub-kingdom now under consideration, a brain and spinal cord are always present, the former being divided into a cerebrum and cerebellum, the latter into the medulla oblongata and proper spinal cord. In the higher Vertebrata, the lobes of the cerebrum are larger than those of the cerebellum, and the afferent and efferent nerves are bound up in

one cord, which joins the spinal marrow by two roots, as in the human subject.

Fishes.—The brain of fishes is composed of several distinct ganglionic masses, arranged in a line with the spinal cord. Next to the cord, posteriorly, is a single ganglion, which represents the cerebellum, and is very large in proportion to the rest of the nervous centres. Further forward are two lobes, or ganglia, arranged as a pair. They are frequently of large size, and communicate directly with the optic nerves, and may, therefore, be termed the optic ganglion. Proceeding still more forward, we find another pair of ganglia, which are comparatively small; they are the representatives of the cerebrum of the higher Vertebrata, but no convolutions mark their surface, and there are no ventricles in their interior, except in the brains of rays and sharks. Just in front of these two cerebral lobes are two small ganglia, connected with the olfactory nerves, and termed, on that account, the olfactory ganglia. Besides these, in some fishes auditory ganglia also exist.



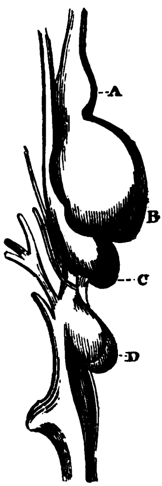
Brain of a Fish.

A, olfactory ganglia; B, cerebrum; C, optic ganglia; D, cerebellum, the spinal cord being below it.

The diameter of the *spinal cord* of fishes does not differ much from that of the brain, and the bulk of the former far exceeds that of the latter organ. The cord varies in different fish, according to the shape of their bodies; but, as a general rule, there is a great resemblance to the spinal cord in man. Thus, in a fish we find the cord divided into two lateral columns by

very deep, longitudinal furrows, and also the spinal nerves arising by two roots, the posterior being provided with a ganglionic enlargement.

Though the above sketch may serve to give a general idea of the arrangement of the nervous centres in most fish, a very great variety of form and disposition of parts occurs in the various species of the several orders. Thus, we may sometimes find the different lobes transformed, or even entirely wanting; but the small size of the cerebral lobes, as regards the rest of the brain, is a constant feature in its arrangement.



Brain of a Reptile.
A, olfactory ganglia; B, cerebrum; C, optic ganglia; D, cerebellum.

Reptiles.—No very great advance in complexity of structure or formation occurs in the brain of reptiles, as compared with that of fishes; but the decreased size of the cerebellum and the increase of the cerebral hemispheres is most remarkable. This is clearly observed in the brain of the frog, where scarcely any cerebellum is found to exist.

The brain of the *turtle* may be taken as a type for that of reptiles generally. The linear arrangement of the ganglionic masses still continues, but at the base of the cerebral lobes the corpora striata and thalami optici can be readily distinguished; the interior of the cerebral hemispheres, moreover, presents a cavity.

Birds.—Throughout all this varied class the arrangement of the nervous system is very uniform. The ganglia cease to be placed in a line with the spinal cord, and assume a position one above the other. There is a considerable increase in the size of the cerebral lobes, which cover all the different sen-

sory ganglia, sometimes even overlapping the cerebellum. As a rule, the cerebral lobes will be found to be smooth on their external surface, but in a few birds a slight marking or convolution can be observed. No large internal cavity exists, as mentioned respecting reptiles, but the relative size of the corpora striata and thalami optici is remarkable, the former being very large and the latter very small. Nor is this so surprising when it is remembered that the corpora striata are connected with the motor functions. The cerebellum is particularly large, which may be accounted for by considering the function attributed to that organ, namely, that of combining muscular movements, as in no class of animals is this power more required. The structure of the cerebellum is laminated, ten or fifteen separate plates composing its mass.

The spinal cord in birds presents a largely developed medulla oblongata, the diameter being at least twice as great as that of the rest of the cord.

Mammals.—Though in the lower order of *Mammalia* there is very little advance presented in the formation of the brain over that of birds, still, in the higher types great differences are exhibited.

In mammals generally, there is a greater development of the posterior part of the cerebral lobes, and a division of the cerebellum into two lateral portions is noticed. The cerebral lobes, indeed, when viewed from above, cover almost entirely the other nervous masses, but it is only in Bimana and Quadrumana that they completely overlap the cerebellum posteriorly. A provision also now first presents itself for increasing the extent of surface of the cerebrum without enlarging the size of the organ. The external surface of the brain of mammals presents numerous *folds* or *convolutions* of the gray substance, which are more marked and distinct in the higher than the lower orders of the class.

In the brains of fishes, reptiles, and birds, no great

commissure, or only one of a very rudimentary character, exists; but in the cerebral organ of mammals a communication between the cerebral lobes on either side is almost invariably present. In the *Marsupialia*, however, the structure of the brain is very simple. Like that of birds, scarcely any traces of convolutions are visible, and the great connective commissure—the corpus callosum—is entirely wanting.

With regard to the spinal cord and medulla oblongata, there is no very marked difference in structure in mammals generally to that of the human subject.

The Influence of the Nervous System on the Organs and Functions of the Body.

The influence of the nervous system on the various organs and functions of the body has been incidentally touched upon, but will now require more special notice.

The nervous system manifestly influences the production of animal heat, the amount of the secretions, and the rapidity of nutrition.

With regard to the influence exerted on animal heat, it is observed that when nerves are divided the temperature of the part supplied by those nerves falls some degrees; but occasionally it happens that when a nerve is injured, without actual separation of its trunk, the opposite effect may result. It has also been demonstrated that if the trunk of the sympathetic ganglia in the neck is cut, the temperature of that side of the head is greatly increased. I have myself noticed a rise of from four to six degrees after the experiment was performed. The amount and quality of secretions, especially the urinary and salivary, are particularly influenced by the nervous system, and more especially by its emotional action. The increased flow of tears in grief or joy is another instance of the power of the nervous force. Though it is not so easy to trace the influence of the nervous

power in modifying nutrition, yet it is well known that it exerts a marked influence on the process.

There is still to be noticed the influence of the nervous on the vascular system which is manifest in the common act of blushing or the quick throbbings of the heart from the emotions of fear or pleasure. In all probability this is due to the action of the cerebro-spinal system, through the intervention of the sympathetic nerves, as this latter system cannot, by its own independent action, produce any such result.

Sleep is a state in which the functions of the cerebrum are, for a time, suspended, so far as they relate to the reception of external impressions; and the more profound the sleep is, the less will it be disturbed by dreams, which are, without doubt, evidence of incomplete suspension of the brain's activity.

There is, most certainly, too, an absolute demand for the rest of the cerebral organ after it has been some hours in activity, a demand which has to be complied with periodically, or which will, if not satisfied, become so urgent that it will force the suspension of the mental functions even under the most adverse circumstances. Thus, it has happened during a naval engagement that men who were greatly exhausted slept near the guns that continued to keep up a heavy fire.

When it is remembered that every manifestation of cerebral activity is attended with waste of the nervous tissue, it will be readily seen that time for repair of the tissue is absolutely necessary; and that this repair cannot go on unless there is a cessation of mental exertion, is also clear.

It is not necessary to enter into the many peculiarities of sleep, its occasional profound or light character, the suddenness with which it sometimes comes on, or the loud noises that *habit* will accustom us to bear without disturbing sleep; still, the capability of *being roused* with greater or less facility is the dis-

tinguishing mark between sleep and coma, where the insensibility is persistent. The length of time required for sleep varies in health and disease, in different persons, and under different circumstances. Habit exerts a great control over the amount of duration, though, as a rule, plethoric persons require long sleep, and very aged people, also, require more lengthened repose than younger subjects.

ANIMAL HEAT.

Chemical action is frequently attended by the evolution of heat, and the existence of heat itself favours chemical action. Thus, the union of oxygen with carbon and hydrogen of the tissues, forming carbonic acid and water, produces a certain amount of animal heat. The respiratory process, which causes the introduction of oxygen into the blood, is, therefore, nearly connected with the maintenance of the temperature of the body; thus, during sleep, when the respiration is slower, the heat of the body is diminished. The oxygen absorbed into the blood meets with hydrogen and carbon, not only as the products of decay of various tissues, but also as free elements introduced in the circulation by the chyle; and as more material is supplied to the blood than is needed for the repair of the tissues, it is probable that the chemical combustion of the superfluous elements assists in giving rise to the evolution of the animal heat.

Fatty matter, which is one of the principal hydrocarbons in the body, is, therefore, a vast source stored up for chemical combustion. As heat can be generated wherever blood is carried, by the action of the oxygen on the hydro-carbons in the fluid, the temperature will be tolerably uniform, and the rapidity of the circulation will almost entirely equalise it.

The nervous system influences the production of heat to a very considerable extent; paralysis or division of nerves supplying certain parts causes a fall of the temperature, a result which also arises from any depressing mental emotion. The flush and heat caused by excited passions, or the rise of temperature in certain diseases and after violent exercise, is chiefly due to an increase of the circulation. On an average, the temperature of the human body is about 98° to 103° Fahr., and the extremes of external heat or cold produce only a rise or fall of two or three degrees.

HEAT, LIGHT, AND ELECTRICITY, EVOLVED BY ANIMALS.

The evolution of heat by animals has already been treated of, under the head of animal heat; but though it is, as therein stated, evolved by warm-blooded animals only, to any considerable degree, yet, to a less extent, it is probably given off by all living beings, as the result of chemical action in their tissues.

The evolution of light and electricity is more rare than that of heat.

The evolution of light is not confined to the animal kingdom, but is exhibited during the growth of some vegetables; thus, certain plants, principally fungi, during the process of their growth, especially if they happen to be in a damp and moist situation, give rise to the evolution of light, and a luminous appearance often takes place in decaying vegetable and animal matter, but the light given out is of a character somewhat different to that evolved during the growth of plants.

In all probability this evolution of light depends on the chemical union of oxygen and carbon.

The phenomenon of *luminous animals* is most commonly exhibited in what is termed the "phosphorescence of the sea," due to the presence of minute creatures, called the *Noctiluca miliaris*. These Infusoria appear to the eye to be small, globular masses of gelatinous substance, with a tail-like appendage. Examined under a magnifying power, one of these creatures appears to consist of a cell full of granular matter, forming the body, any part of which has the power of evolving light, as the numerous bright points seen in the substance shift rapidly about the interior of the sac or cell-wall. When pressed the bodies of these animals emit light more brilliantly, and when the cell-wall is treated with acid, contraction ensues and a powerful evolution of light follows, which, however, rapidly ceases, evidently from the death of the animal. Dr. Pring has made many interesting experiments on the subject, but no definite conclusion as to the source of the luminous appearance has been arrived at.

In the tropical regions the phophorescence of the sea frequently depends on the presence of certain Acalephæ, from whose skin a mucous exudation takes place, which has the power of giving a phosphorescent lustre to any fluid with which it is mixed.

Many *Molluscous* animals are endowed with this singular power of evolving light, the class Tunicata being specially remarkable for the character.

Amongst the *Articulata*, some of the Annelida and Insecta present the same feature; of the latter, one family alone possesses nearly 200 species of luminous animals.

The *glow-worm* may be taken as an example. On the ventral surface of the bodies of these little animals are minute sacs, full of granular matter, through which the delicate tracheæ or air-passages ramify in a close network. The luminous appearance here evidently depends on the access of air to these sacs, for when the supply is shut off the evolution of

light ceases. A supply of pure oxygen to these animals greatly increases their brilliancy, the light evolved depending on a rapid union of the oxygen with the tissues, generating carbonic acid.

Vertebrata does not comprise any animals which have the power of evolving light unless, indeed, it is true that a certain kind of frog found in Surinam has the power of emitting light from its mouth.

The Evolution of Electricity.—The laws of electricity show that bodies may be divided into electrics and non-electrics; the former being non-conductors, the latter conductors. Electrics, when excited, produce electricity, but are incapable of conveying the fluid away.

Friction and heat are the chief agents required for the development of electrical force, but it may be also abundantly induced by chemical action or a magnetic current. But besides these causes of electrical excitement, the influence of the nervous system, or the nerve force, has, in certain animals, the power of generating electricity.

From numerous experiments it has been proved that during the growth of plants a constant evolution of electric force takes place, and that even a fixed and determined *polar* condition has been observed in fruit. Thus, it is stated that the stalk end of a *peach* is the negative pole, and the eye the positive, and that the reverse is the case with an apple or a pear. Nutrition, then, and a process of growth or molecular change, has a tendency to disturb electrical equilibrium, and this will apply equally to the nutrition or growth of animals or plants; indeed, all parts of an animal's body are in different electrical conditions; thus, a battery or *pile* can be made from a piece of newly severed muscle, and it may be proved that the external and internal parts of the structure are in different electric states in the following manner:—Suppose the leg of a frog to be cut off from its body, and the great nerve of the leg, the crural, to be dis-

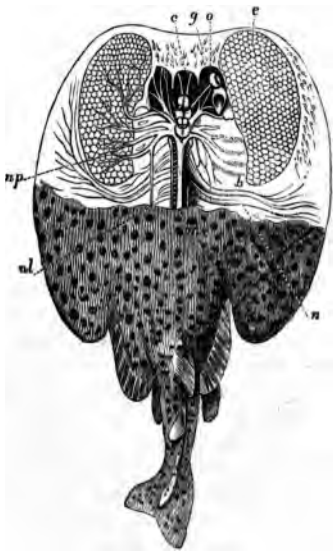
sected out and left hanging; the nerve is then split in two and insulated, except at the free extremities or ends of the split part, the preparation being termed the "*galvanoscopic frog.*" A deep incision must next be made in the piece of muscle which is destined to act as the battery, and into the very bottom of the wound one filament of the crural nerve of the frog's leg must be inserted; at the same time the other filament must be so arranged that it is in contact with the external part of the muscle. Immediately this has been done, if the muscle has been recently severed from a living animal (especially if from a cold-blooded animal), the limb of the frog will be thrown into contraction, proving that there was a difference in the electrical condition of the internal and external part of the muscle acting as the pile.

Without detailing the effects of electrical agency on muscular and nervous tissue, or demonstrating the fact of a continuous electric current, flowing in certain directions in the bodies of animals, we pass on to the consideration of a class of animals which have the power of accumulating the electric fluid and discharging it at pleasure in a concentrated form, giving rise to a very perceptible and sometimes violent shock.

The *torpedo* and *Gymnotus electricus* are animals commonly cited as examples; but, besides these, the *silurus*, a species of salmon, the *trichicarus* or Indian sword-fish, and some others, possess the power of generating electricity.

The *torpedo* is shaped like a skate, and is a species of the Ray tribe; it is found abundantly in the Mediterranean and Atlantic, being much employed as an article of food. The body of this fish is smooth, and presents the appearance of nearly a circular disc, from which a narrow tail extends backwards. In the torpedo the brain is provided with a *large* nervous mass, called the *electric lobe* or *ganglion*, situated behind the cerebellum, and connected

with the medulla oblongata. From this electric lobe arise several large nervous trunks, which run to the electrical organs; these nerves seem to be analogous to the pneumogastric of other animals. That the origin of the electrical force is in these lobes, can scarcely be doubted; for, if the nerves issuing from them are severed, or the lobes themselves destroyed, the power of evolving the electric fluid is totally lost. The development and manifestation of the electric power takes place, therefore, through the agency of the so-called electrical organs, the structure and arrangement of which may be next noticed.



The Torpedo: *c*, brain; *e*, electric organ; *m e*, spinal cord; *n*, *n l*, *n p*, nerves; *g*, the head; *o*, the eye.

The *electrical organs* are two in number, situated on either side of the head; they consist of a double layer of membrane, which is arranged so as to form a many partitioned chamber. These divisions break up the whole organ into a number of columnar-shaped spaces; the ends of each column being directed towards the two opposite surfaces of the body.

Besides these greater partitions, others more delicate traverse the structure at right angles to the direction of the columns, dividing each one of them into

a number of distinct cells. The partitions between the cells are thin, but they are richly supplied with blood-vessels and nerves; the terminal branches of the latter breaking up into minute plexuses, and spreading over the cell-walls. Filling the interior of the cells, is a soft gelatinous matter, consisting of water, albumen, and common salt.

Such being the structural character of the electrical organs, it may easily be supposed that the nervous agency acting on the contents of each of the cells disturbs the electrical equilibrium of the contained matter, portion of it becoming positive, and the remainder negative. Thus, the combined action of the cells in any one of the columns would convert that column into an electric pile, the two extremities of which would necessarily be in opposite electrical conditions, and the requirements for the production of an electric shock fulfilled.

The *Gymnotus electricus* belongs to the eel tribe, inhabiting the waters of South America, and possessing greater power of generating the electric fluid than any other fish; indeed, so strong are the shocks, that a single discharge is sufficient to kill a man.

The *electrical organs* are arranged in four fasciculi along the back and tail; the structure resembling that of the electric organs of the torpedo.

The purpose served by this provision for accumulating and discharging the electric fluid is variously stated; it may serve as a means of procuring prey, or as a weapon of offence or defence; at the same time, it has been supposed to assist the respiratory function, by decomposing the water near the gills of the fish, and thus setting free a supply of oxygen. Whatever may be the correct explanation, it is certain that there is a limit to the power of producing the electric fluid; for, if the fish are irritated, and induced to give frequent or repeated shocks, the power diminishes, and at length ceases; and is not renewed till the animal has recovered from the

exhaustion produced by the over-stimulation of the nervous centres. In capturing electric fish, advantage is taken of the knowledge of this fact: horses or other animals being driven into the water, the fish exhaust their nervous power by continually discharging the electric fluid against the intruders, and may then be drawn to land with safety.

SENSATION.

SENSATION may be defined to be the "*perception of impressions,*" whether received externally, or originating in some internal cerebral action. Impressions may be received, transmitted to the nervous centres, and produce their reflex results, without any perception of the action, or, in other words, without producing sensation; this has been already referred to in speaking of the function of the spinal cord and brain; and with regard to the latter organ especially, actions which usually require the exercise of the will, and which are attended with sensory impressions, may occasionally become perfectly reflex or automatic, as is the case in walking during sleep. On the other hand, sensations may originate and become vividly recognised from the action of the cerebrum alone, without any external impression. In this way the mind originates an idea which produces a sensation as real as though it was caused by external impression. No better example of this fact can be cited than that related by Professor Bennett, "A butcher hanging up a piece of meat slipped, and ran the hook into his arm, remaining suspended by it; on being taken down, he was pale, almost pulseless, and gave symptoms of great pain when his arm was moved, crying out repeatedly whilst his sleeve was cut open; but, on being exposed, his arm was found to be entirely uninjured, the hook having

merely penetrated the sleeve of his coat." Here the sensations produced were as real as though they had been induced by the external impressions which an actual wound would have occasioned. Thus, intensely excited mental action, or implicit belief that a certain train of circumstances will take place, is often followed not only by the sensations which external impressions would produce, but also by functional changes and reflex actions; thus, it has happened that purging and vomiting have followed the swallowing of perfectly harmless and inert substances, where the person had previously been induced to believe firmly that the above results would take place. In this way we may account for many of the effects produced by mesmerism, electro-biology, &c., or for the manner in which persons sometimes foretell the date of their death—a strong mental belief tending to bring about the actual result.

Impressions, when not attended to, may not be felt or recognised by the mind, as is frequently the case when the attention is particularly directed to other objects. Habit, or a repetition of the same impression, has a tendency (as a general rule) to deaden or blunt the sensations, but only where the impressions are not attended to from their frequent repetition; for, if the attention is strongly fixed on them, their recurrence strengthens rather than diminishes the sensations produced. In this way blind persons, by constantly directing their attention to the impressions made on senses of touch and hearing, in time have the acuteness of the sensations greatly increased.

The capability of receiving impressions which produce sensation varies greatly in different tissues; as a rule, vascular structures are the most sensitive, a free supply of blood being necessary for nervous activity. The substance of the nervous centres is itself particularly insensible to impressions made by absolute contact with external matter; thus, the brain may be sliced away without pain. It appears that

the most sensitive structure (or rather the structure most capable of receiving impressions and transmitting them to the brain) is the skin, to which a delicate and minute plexus of nerve fibres is distributed. Excited vascular action in inflammation increases the sensibility of parts; and the application of cold, retarding the circulation, deadens the structure to external impressions.

Hunger and Thirst.

Before entering into a description of the special senses, we may consider two varieties of sensation, one of which is referred to the stomach, and is called *hunger;* the other referred to the throat, and termed *thirst;* the former indicating a demand of the system for food, the latter showing that a requirement for a supply of fluid exists.

The sensation of hunger is a peculiar sinking and gnawing feeling, referred directly to the stomach, and occasioned, probably, by some irritation to the nerves distributed to that organ.

Mere emptiness of the stomach is not sufficient to cause the sensation, for the stomach is soon emptied, even after a full meal, without any such sense of hunger being produced; though it is equally true that the sensation of hunger may be allayed by the introduction of indigestible matter. Indians on a march or journey will sometimes swallow earth, to stay the unpleasant feeling when they are in want of food. And again, nutritive material introduced into the circulation by other means will arrest the sensation of hunger. It may therefore be possible that a certain want felt by the system, communicates as it were, its requirements to the sympathetic nerves, which by their action cause a congested state of the lining membrane of the stomach, which, being ready, but unable to pour out the gastric secretion, on account of the absence of food, produces irritation of the nerves

distributed to the gastric organ, and thus induces the sensation of hunger.

Thirst is a sensation differing from that of hunger, being referred to the back of the throat or fauces, indicating the demand made by the system for a supply of fluid.

The Senses.

Certain organs are supplied with nerves which are capable of receiving only one kind of impression, or being acted on by one particular stimulus; these nerves are termed those of *special sense.* Impressions which affect one nerve of special sense will not influence the others; thus, light only stimulates the optic, and sound the auditory nerve.

The senses are five in number—touch, taste, smell, sight, and hearing. The last four are *special.*

The Sense of Touch can scarcely be considered as one of the special senses, though it nearly approaches to them.

The cutaneous covering of the body is particularly well adapted for receiving tactile impressions, from the abundant supply of nerve fibres distributed to the structure. Of these two varieties may be distinguished: first, the looped termination of the sensory nervous branches; and second, the nerves contained in the little projections or papillæ which stud all parts of the skin. The papillæ, as already described, are small conical projections, situated under the cuticle, composed of a loop of nerve fibre and a loop of capillary vessels. In the more sensitive parts of the cutaneous surface, the papillæ contain an internal "axile body," consisting of areolar tissue, covered with a layer of elastic tissue. Perception of the presence of external objects is obtained by the sensation produced through impressions made on the nerves and papillæ of the skin, by actual contact with external bodies; but the hardness or softness of different substances is

judged of rather by the resistance offered to the muscular power which is exerted in grasping them, than by the mere contact of the skin with the bodies touched.

The appreciation of temperature also takes place through the medium of the cutaneous nerves; for it has been found that heat or cold applied to raw surfaces only produces the sensation of *pain*, without giving rise to relative ideas of temperature.

The degree of sensibility of a part bears direct relation to the number of papillæ it contains, and the thickness of the epithelial covering; thus, the lips and palms of the hands, which are more thickly studded with papillæ than the skin on the back of the hand or foot, are much more sensitive to tactile impressions.

Professor Weber determined the amount of relative sensibility by touching the surface of the skin with the legs of a pair of compasses, the points being guarded with small pieces of cork, and the eyes of the person closed during the experiment. He found that in certain situations the legs of the compasses must be widely separated before a distinct perception is obtained that the skin is being touched by *two* distinct points; and in other places that the legs of the instruments may be closely approximated, and the impressions made by the two points be clearly felt. Thus, at the tip of the tongue, the two points were perceptible when the compass-legs were but half a line apart; but on the skin over the spine it was found that the legs must be thirty lines apart before two distinct impressions were communicated; for when the legs of the compasses were more closely approximated, the contact of the two points merely gave the impression that the surface was being touched by one point only.

The following are the results of some of his observations:

The two points can be distinguished	by the tip of the tongue, when only ½ a line apart.
" "	by the skin on the palm of the hand, when only 5 lines apart.
" "	by the skin on the back of the hand, when only 14 lines apart.
" "	by the skin over the spine, when only 30 lines apart.

The degree of sensibility, however, may be greatly augmented by habit or practice; blind persons have even educated the sense to such perfection, that they could distinguish different colours by the touch alone. Again, the capacity of certain parts (which are not very sensitive to ordinary impressions) of recognising impressions of a peculiar character is remarkable; thus, the skin of the soles of the feet, under the armpits, and on the sides, though possessing an acuteness of tactile perception far below that of the tips of the fingers or red part of the lips, is capable of being stimulated by the action of "*tickling*" in a manner that will not affect the more sensitive parts.

The *Sense of Taste*, may be almost regarded as a modification and refinement of the sense of touch, assisted by the sense of smell; but the sense of taste, especially when stimulated by very bitter or very acid substances, produces impressions distinct from any that mere tactile impressions would cause, and which often arise without any assistance from the sense of smell.

The *Tongue* is the special organ of taste, but the sense is not limited to this structure, as it exists in the palate and fauces.

The tongue is a muscular structure supplied by two nerves, the glosso-pharyngeal and gustatory, the latter being a branch of the fifth. An epithelial layer covers the surface of the lingual structure, and embedded in its substance are certain conical projections, resem-

bling the papillæ of the skin. These papillæ are of two kinds, *simple* and *compound;* the former lie entirely under the epithelium without giving rise to any prominences indicating their presence; the latter show themselves as projections on the surface of the organ.

The *simple papillæ* stud the entire surface of the tongue, and in a general way their structure resembles that of the cutaneous papillæ, except that nerve fibres have not been traced in them.

The *compound papillæ* may be divided into three varieties, the *fungiform*, *filiform*, and *circumvallate.*

The *fungiform* project considerably from the surface of the tongue, being scattered here and there on its tip and sides; they consist of a vascular plexus of capillary vessels and terminal meshes of nerve fibres. Covering these papillæ is a thin layer of epithelium, so thin, indeed, that the colour of the blood circulating in the papillæ is clearly visible, giving them the appearance of little red projections on the surface of the tongue.

The *filiform* are so called from the hair-like processes which spring from their free extremities; they consist, like those just described, of meshes of nerves and blood-vessels, but they are destitute of any epithelial covering. They are situated round the fungiform papillæ, and are much more numerous.

The *circumvallate papillæ* are few in number, eight or ten only being usually present, arranged at the base of the tongue in the form of the letter V; their name indicates their appearance. They present a central mound surrounded by a furrow and then a wall of mucous membrane; internally, they are made up of a clump of papillæ resembling the "simple," and covering the whole, is a layer of epithelium.

The method in which substances produce their effects on these papillæ, is uncertain, but it appears tolerably evident that the sense cannot be called into action unless the substance tasted is soluble in the

fluids of the mouth. Many things give certain impressions to the tongue, which are not the same as those arising from the stimulation of the nerves by matter dissolved in the mouth; thus, marble from its coldness appears to have a taste. Metals, especially two metals, produce a sensation of taste from galvanic action, and temperature also influences the sense in a marked degree. Extremes of heat or cold, entirely blunt the sensations and destroy the power of distinguishing flavours. Habit, and the frequent over-stimulation of the lingual nerves, in time deadens their sensibility, and the repetition in quick succession of similar flavours soon produces one kind of impression only.

The Sense of Smell is closely allied to the sense of taste, and is stimulated or called into action by the influence exerted on the olfactory nerves by effluvia which emanate from various substances, but as it is not certain of what their odours consist, it is difficult to explain how they act on the olfactory organ; in all probability, small particles of the bodies which emit odours, float in the air, and coming in contact with the olfactory nerves, make certain impressions upon them which produce the sensation of smell; and to assist this action, a current of air is constantly traversing the nostrils.

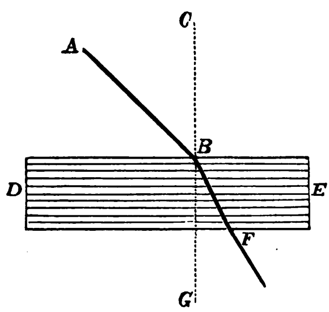
The nerves of smell, or the olfactory nerves, are derived from the first cranial nerves, and are distributed to the lining membrane or Schneiderian membrane of the nose. The olfactory nerves are peculiar in structure, inasmuch as they present no white substance, being composed entirely of gray matter.

But little is known of the way in which effluvia act on these nerves, or what produces the difference between agreeable and disagreeable odours. In animals, the sense is considerably modified, and serves purposes different to that which it performs in man. The chief use of the sense of smell, is to dis-

tinguish offensive from pleasant odours, the former being usually injurious.

The Sense of Vision.—Perhaps the most delicate and complicated organ is that which is specially adapted for receiving the impressions of rays of light on the optic nerve; but before entering into a description of the construction of the eye, it will be well to consider, first, the laws which govern the transmission of rays of light through different media, and more especially media in the form of lenses. Rays of light proceed from luminous bodies in *all* directions, and as long as they are propagated through the same medium, so long do they continue to proceed in right lines; but when the rays encounter media of different density, they are refracted or bent from their course.

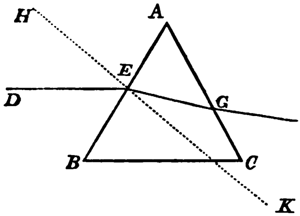
In all cases, when passing out of a rare into a dense medium, a ray of light is refracted *towards* a perpendicular, raised from the surface of the denser medium at the impinging point. Thus, suppose A B is a ray of light, passing through air into a denser medium, D E, impinging on its surface at the point B; the ray enters the denser medium, and as it passes through it takes a direction different to that which it followed before it passed into the dense medium, and it will be



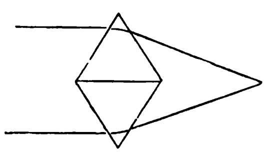
found to be bent towards a perpendicular, C G, called the *normal*, which is drawn at *right angles* to the surface of the medium D E, at the point B. In the same way, when the ray passes out again from the medium into the air beyond, or into one which is less dense, it is again bent from its course, but this time it is bent *away* from the normal line.

The amount of refraction of a ray depends on the difference that exists between the media through which it passes; thus if it passes out of a rare into a dense medium, it will be greatly refracted; but if the two media are nearly of the same density, but little refraction will take place.

The form of the refracting media, however, also influences the direction of the rays passing through them. Suppose A B C is a prism of glass, and D E a ray of light passing through the air and impinging on the surface of the prism at the point E, the ray continuing on through the prism will be bent from its original course, D E, and take the direction E G; now draw an imaginary line, the normal, H K, through the point E, at *right angles* to the surface of the medium, and it will be found that the ray D E G is bent towards the line H K.



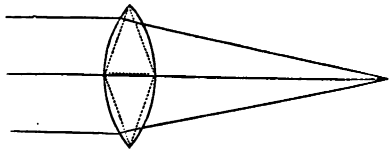
A ray, therefore, passing through a prism is bent towards the base or thick part of the prism; but on passing out of the glass again, the ray is refracted a second time; but then it is bent from the direction of the normal. The refraction, however, is not sufficiently great to bring it into the old direction, D E, that it had previous to entering the prism.



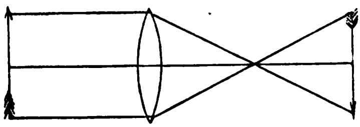
It will be seen, therefore, that if two prisms are placed base to base, and parallel rays of light impinge upon each of them, the rays will be bent towards the bases of the prisms, and will eventually meet at a point on the other side, termed the *focus*.

A double convex lens is nothing more than a modifi-

cation of the two prisms placed base to base, and the manner in which the rays of light are brought to a focus by this kind of lens, will readily be understood. The line passing through the centre of the lens will, of course, suffer no deviation of its course as it enters the glass at right angles to its surface, and would, therefore, correspond with the normal.



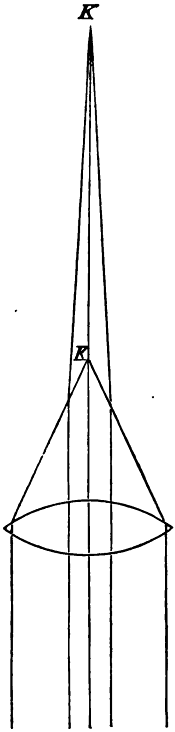
The manner in which a lens forms an image on a screen placed behind is very simple; the rays of light pass through the lens, and meet at a point on the other side; but of course they do not stop there; they still proceed onwards and cross each other. The image on the screen, therefore, will be inverted, as in the figure of the arrow here drawn. A lens does not form a perfect image; it has two defects: it is evident that rays of light passing through the edge of a lens where the surface is inclined at a different angle to the surface of the centre, will be more bent than those which pass through the central portions, and will, therefore, come to a focus at a different place.



In the following figure,* K will be the focus formed by the outer rays, and the focus formed by the rays passing through the central part of the lens will be at the point K.′ This is called the *spherical aberration* of the lens. The defect may be corrected by using a diaphragm, which cuts off some of the rays, and only permits them to pass through the central part of the lens. There is still another defect which a common lens presents—a ray of light passing through a prism splits up into its prismatic colours, so that when the

* See fig., next page.

image formed by the lens is thrown on a screen, rings of colour will be seen surrounding the picture. This is termed *chromatic aberration*, and may be remedied by making a lens of two different kinds of glass, one more dense than the other, so that the density of the whole lens is equalised



THE HUMAN EYE.

The human eye is of a spheroidal form, with a slight projection in front; the whole organ consisting of an investing coat composed of different layers or tunics, and an internal cavity filled with various humours.

Externally, the globe of the eye looks white and shining, with a transparent circular portion in front, which is termed the *cornea;* and from the posterior part of the organ passes a round white cord of nerve substance (the optic nerve). Attached to the sides of the eyeball are the tendons of six muscles, four straight (*recti*) and two oblique (*obliqui*); and covering the whole anterior surface is a delicate membrane called the *conjunctiva.*

The wall of the eyeball consists of three coats or tunics, called *the sclerotic, the choroid,* and *the retina.*

The external coat is the sclerotic, next to it is the choroid, and most internally, the retina.

The sclerotic is a dense, white, fibrous membrane, thicker at the posterior part of the eye, constituting

what is termed the "white of the eye," and covering in the entire globe, except at the front, where a circular aperture is left for the cornea, which completes the external coat of the organ, the sclerotic forming four fifths and the cornea one fifth of the whole.

Attached to, and investing the sclerotic anteriorly, are the expanded tendons of the recti muscles, their tendinous expansions being called the "tunica albuginea;" and covering the whole anterior surface, even of the cornea, is a delicate mucous membrane, termed the conjunctiva, which also lines the internal surface of the eyelids.

The *cornea* is the hard, transparent projection in the front of the eye; it is circular in form, and shaped like a concavo-convex lens; its edges are beveled off, and united to the margin of the opening in the sclerotic. The cornea is composed of three principal layers: —1st, the anterior elastic lamina; 2nd, the cornea proper; and, 3rd, the internal elastic lamina. The middle layer, or cornea proper, is itself composed of about sixty different layers, which do not differ much in structure from the fibrous sclerotic, except that they are perfectly transparent.

No blood-vessels have been detected in the cornea, but numerous capillaries run up to the margin of the structure, and then loop back again without entering its substance. In inflammation, however, vessels are clearly seen jutting into and across the cornea; it is, therefore, probable, that minute channels do exist, but that they are too minute to admit blood corpuscles, or be detected by the most careful examination.

The *choroid.*—Lining the internal surface of the sclerotic, is a dark-coloured, vascular membrane (the choroid), composed of a close network of blood-vessels and pigment-cells. The whole structure is extremely vascular, and assists, probably, in maintaining the heat of the retina—a function which, considering how much the eye is exposed to cold, is very important. At the anterior part the choroid ends in numerous *folds called the ciliary processes.*

The *retina*.—The optic nerve enters the posterior part of the eye, piercing the sclerotic and choroid coats, and, expanding into a membranous form, constitutes the retina. At the spot at which the nerve enters it is insensible to light; the point of entrance being situated on the inner side of the centre or axis of the eye, the "blind spot" cannot be directed on any object by *both* eyes at the same time. As the optic nerve enters the organ, it divides into numerous branches, which spread themselves out and form a network or plexus of nerve fibres, consisting entirely of gray matter; besides this, there is a very minute capillary plexus spread over the nerve structure, and separating it from the choroid is a layer of cells called the *membrana Jacobi*. In one particular part of the retina is a yellow spot, the foramen centrale so called, though it is not an aperture, but is composed of transparent nerve substance, the fibrous part of the retina being absent, and the cell structure with the membrana Jacobi alone being present. This spot is by far the most sensitive part of the whole membrane; and it is said that for perfectly accurate vision an image must be depicted on this part of the retina.

Internal Structure and Chambers of the Eye.

The internal cavity of the globe of the eye contains two chambers, the anterior and posterior, both filled with a fluid called the aqueous humour; the remaining portion of the cavity being filled with denser media, called the crystalline lens, and vitreous humour.

The *Iris*.—Dividing the anterior from the posterior chamber is a muscular curtain called *the iris*, pierced by a circular opening termed "the pupil." The iris is the *coloured* part of the eye, the tint of the pigment varying in different people. This curtain is composed of two layers of muscular fibre, the posterior being *disposed* in a radiating manner, and the anterior in a *circular* band at the margin of the pupil. The radi*ating* layer consists of unstriped muscular fibre, which

together with the circular band, are supposed to give the power of dilatation and contraction, thereby enlarging or diminishing the size of the pupil. Scattered through the substance of this tissue, and covering the posterior surface, are numerous irregular-shaped pigment-cells, which give the colour to the iris; but in the albino the pigment of the choroid and iris is wanting, the colour of the blood-vessels giving a red appearance to the eye.

The *Crystalline Lens.*—Immediately behind the iris is a transparent, lenticular-shaped body, called the crystalline lens. Its form is that of a double convex lens, the posterior surface being more convex than the anterior, and its structure consisting of about 200 layers, composed of delicate, serrated fibres. The outer part of the lens is less dense than the centre, and the whole is enveloped in a transparent membrane, called "the capsule of the lens."

In front of the crystalline lens, filling the anterior and posterior chamber, is the aqueous humour, and behind is the vitreous body.

The *anterior chamber* is the space between the inner surface of the cornea and the front of the iris; it communicates with the *posterior chamber* through the opening of the pupil.

The *posterior chamber* is much smaller than the anterior, being the space between the back of the iris and the front of the lens and vitreous humour. Both chambers are filled with the aqueous humour.

The *Aqueous Humour* occupies the anterior and posterior chambers of the eye, between the cornea and lens. This fluid is chiefly composed of water, containing a little common salt, and is secreted abundantly from a membrane lining the posterior surface of the cornea; so that if the humour escapes, as it frequently does in operations on the eye, it soon re-collects.

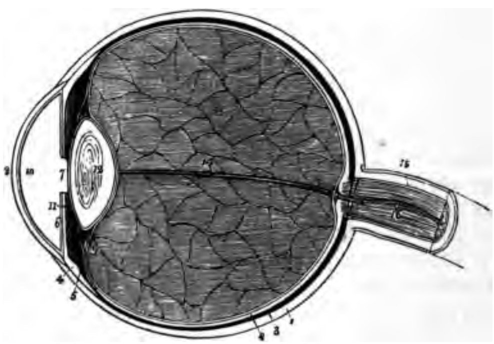
The *Vitreous Humour.*—Lying between the lens and retina, is the vitreous humour, enclosed in a delicate membrane, termed the tunica vitria, or hyaloid mem-

brane, which sends processes into the interior of the humour, splitting it up in a cellular manner, the interspaces being filled with a clear fluid, the whole substance having a jelly-like consistency.

The *hyaloid* membrane, enclosing the vitreous body, is a transparent fibrous covering, in contact by its outer surface with the retina, and at the anterior part with the back of the crystalline lens. All these contained media just described, namely, the crystalline lens and its capsule, the aqueous humour, the vitreous body, and the hyaloid membrane, are perfectly transparent.

The *suspensory ligament* of the lens, situated round the edge of the lens, is a fibrous ligament, which assists to retain the crystalline body in its position in front of the vitreous humour. Between the ligament and the hyaloid membrane runs a little canal round the margin of the lens, called the "canal of Petit."

The *ciliary ligament* is a band of white fibres, attached to the sclerotic at the internal surface of the margin of the cornea, serving to suspend the iris.



The Human Eye: 1, the sclerotic; 2, the cornea; 3, the choroid; 4, ciliary ligament; 5, ciliary processes; 6, the iris; 7, the pupil; *8, the retina*; 9, canal of Petit; 10, the anterior chamber; 11, posterior *chamber*; 12, the lens; 13, the vitreous humour; 14, artery of the *lens*; 15 and 16, the optic nerve.

The *ciliary muscle.*—Between the posterior surface of the ciliary ligament and anterior part of the choroid coat, are a few unstriped fibres of muscular structure, termed the ciliary muscle.

The *ciliary processes.*—At the anterior part of the choroid it is arranged round the margin of the lens into a number of folds or plaits, called the ciliary processes; they are about sixty in number, and connected with the hyaloid membrane and posterior part of the iris.

Such being the anatomical structure of the organ, we must next consider its functions; but before proceeding to these, the muscular apparatus by which the eyeball is moved, and the lids by which it is protected, must be briefly noticed.

Muscles of the Eye.

The ball of the eye is situated in a bony cavity, the orbit, which also contains the lachrymal apparatus, the muscles, and a considerable quantity of fat, this latter substance forming a cushion on which the eye rests, resisting the tendency that the recti muscles have to draw the eyeball back into the socket. In disease, however, when the fat is mostly absorbed, the muscles act without restraint, and produce that sunken appearance of the organ so commonly seen.

The muscles of the eye are six in number, four recti, and two obliqui.

The *recti* muscles move the eye upwards, downwards, and laterally; the *obliqui* partly turn the globe on its axis. Any two or more muscles may act together, and their combined action turn the globe of the eye in all directions.

The *eyelids* are muscular flaps, stretched on a rim of cartilage, covered with skin externally, and lined by the conjunctiva. They are destined to protect the eye by shielding it from dust, and by spreading over the surface a film of fluid at each act of nictitation or winking. With respect to their action, it may be

briefly observed that the upper lid (or that which is movable) is supplied with a muscle—the *levator palpabræ*—which when in action raises the lid, but when not acting permits the lid to fall; and as no muscular action can continue without intervals of repose, at certain periods the muscle ceases to act, and the lid falls, producing the act of nictitation; at the same time it serves to spread the secretion of tears over the conjunctiva, and gives a short rest to the retina.

The *lachrymal gland* secretes the tears, and is situated in a hollow at the upper and outer part of the orbit. In form, the gland somewhat resembles an almond, and in structure it resembles the salivary glands; from it six or eight little ducts convey the secretion to the outer part of the upper eyelid, opening on the inner surface.

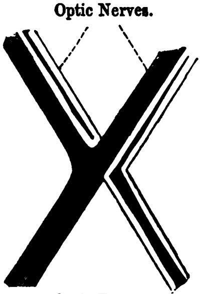
The *eyelashes* and *eyebrows* shield the eye from light and dust, and prevent the sweat from running down the forehead into the aperture between the lids; thus, in warm climates, where the sun is generally powerful and the light strong, the eyebrows are specially developed.

Passing from the globe of the eye to the brain are the optic nerves, serving as the communicating channel through which impressions made on the retina are transmitted to the nervous centre. A description of these nerves must next be given.

The *optic nerves* are two round, white cords of nerve substance, passing from the back of the eyeball through the posterior part of the orbit to the brain. In their course the two nerves converge, and at the base of the brain meet, and, uniting, form what is termed the *optic commissure*, from which the nerves continue again as two separate flattened bands, called the *optic tracts*, terminating or becoming lost in ganglionic masses at the base of the brain, called the *thalamus opticus*, and geniculate body.

In the optic commissure a peculiar decussation of

the fibres of the two nerves takes place; thus the optic tract of the right side contains fibres from the right optic nerve, blended with other fibres which cross through the commissure from the left; in a like manner, the left optic tract contains fibres both of the right and left optic nerves.



Of Images formed on the Retina.

The structure of the eye having been anatomically considered, it will now be necessary to regard it as an optical instrument.

From the account already given of the organ, it will be seen how closely it resembles the camera obscura. The light, passing through the cornea, crystalline lens, and vitreous humour, forms an image of external objects on the expanded retina, and producing certain impressions, which, being communicated to the brain, convey to the mind the idea of the form and colour of surrounding bodies.

The dark choroid lining of the chamber of the eye prevents any diffusion or undue reflection of the rays after they enter through the crystalline lens, the same purpose being served in the camera by blacking the interior of the box. The two defects already spoken of to which common lenses are subject, namely, spherical and chromatic aberration, are counteracted by the arrangement of the iris, crystalline lens, and vitreous humour. The iris forms a kind of diaphragm, and the lens being so constituted that the denser portion is towards the centre, the two kinds of aberration are rectified.

When the rays enter the eye they pass through the cornea and aperture of the pupil, and then through the crystalline lens, cross each other just behind that

body, and, traversing the vitreous humour, come to a focus on the retina; but in some instances the focus is formed before the rays reach the retina, and in others the focal distance is beyond that membrane; in either case an imperfect image will be formed on the retina, and no clearly defined impression will be produced. These two defects are termed, respectively, short and long sight, the former occurring usually in young persons, and the latter in old.

In short sight, or *myopia*, the rays from distant objects cross each other too soon, and come to a focus before they reach the retina. This defect arises from too great a *convexity* of the cornea or crystalline lens, or from too great a *refractive* power of these or other media in the eye; and it may be remedied by the use of *concave* glasses, which compensate for the defect.

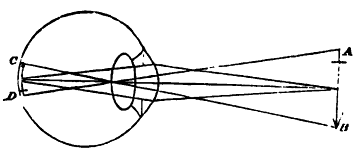


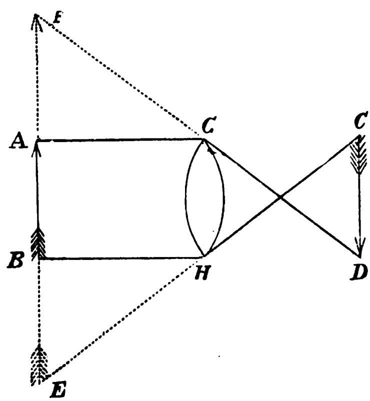
Image formed on the Retina of the Eye
A B, an object; C D, the retina.

In long sight, or *presbyopia*, the rays from distant objects come to a focus on the retina, but those from near objects are not sufficiently refracted, and therefore their focal distance is beyond the retina, so that the image formed on it is out of focus. Thus, persons whose sight is of this character cannot distinguish objects close to them, whereas short-sighted people are able to see very minute bodies, when close to their eyes, much more distinctly than persons whose sight is adapted for either long or short distances.

The defect of long sight arises from a flattening of the cornea or lens, or from too little refractive power of the contained media of the eyeball; the defect may be remedied by the use of convex glasses.

Cause of Erect Vision.

From the foregoing illustrations it appears that the image depicted on the retina is inverted; the question therefore arises—how is it that we see things in their actual position? and to this question many answers have been given, and many theories started as an explanation. Some say, that if everything we see is inverted on the retina, it comes to the same thing as if they were represented without being so inverted, as the *relative* position remains the same in either case; others support the doctrine that we see correctly because we *learn* to do so, and that the mind refuses to see objects upside down, because we know by actual experience that they are not so placed. But an explanation, which seems much more satisfactory, is that "the eye looks for an object in the direction in which the rays of light from it impinge on the retina;" thus, suppose rays pass from the arrow A B, through the lens G H, and form, on the opposite side, an image of the arrow D C; and



supposing this image to be formed on the retina, the rays striking it in the oblique direction G D and H C, the eye looks for the object in the direction in which these rays come, and therefore will see the arrow magnified to the size F E; and thus the object

appears in its proper position, though its image on the retina is inverted.

The picture of external objects formed on the retina must necessarily be very minute; and it is wonderful that every part, even when a large field of view is taken in, should be distinctly and clearly depicted, and defined to the sense; but it is supposed that the sensitive spot alone is capable of receiving very delicate impressions, and that those received on the rest of the membrane are of a more general character, so that when we wish to see anything very distinctly the object must be delineated on the sensitive spot. It is well known that we may glance over a landscape and not observe some particular object in it, till our attention has been specially directed to the place; and it may also be observed that, when viewing a large picture, and examining every portion attentively, the eye rapidly runs over the whole surface, otherwise the detail cannot be appreciated, though a general impression may be obtained.

The Cause of Single Vision with the two Eyes.

It is evident that when both eyes are directed towards one object—its image will be formed on each retina, and that two distinct pictures will be produced, though the mind only recognises one impression, or rather only has conveyed to it the idea of a single object. The cause of this single vision with the two eyes has been variously explained, but if it is remembered that the eye looks for the object in the direction in which the ray strikes the retina, it will be seen that the lines of "visible direction" are referred by both eyes to the same spot, and, therefore, that the image seen by one eye is superimposed on that seen by the other, a perfect idea of the object being thus obtained.

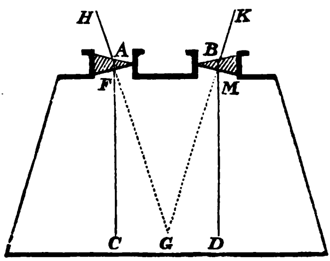
The introduction of the stereoscope enables us to

explain the necessity of binocular vision to obtain a correct idea of the distance and form of objects. On a stereoscopic slide two pictures are represented, but on close examination they are found not to be exactly similar; they are, in fact, representations of the same object taken from a slightly different point of view, or, in other words, at a different angle. This is the case also with the images formed in the two eyes; the picture on each retina is not exactly the same, for the eyes, being situated at a short distance apart, view the object on which they are directed at a slightly different angle. It may easily be proved that the images depicted on the two retinæ are not the same by the following experiment:—Close the right eye, and hold a book a few inches in front of the left, so that one end of the book only is visible; then open the right eye, and one side of the book will come into view; the image, therefore, formed on the left retina, is merely that of the end of the book, but that on the right is a picture of the end and side as well, the combined effect of the two images giving the idea of the book as it actually exists. The idea of solidity is not conveyed to the mind unless an object is viewed with both eyes, for unless the images formed on the retina are both referred to one spot, and these superimposed, as is the case in the stereoscope, the object viewed will not stand out in relief. It will facilitate the explanation to enter into a brief description of the stereoscope, and the manner in which it produces its peculiar effect of combining two pictures, giving the idea of the existence of one only, each part of which seems to be as palpably solid as the actual body or view that is represented.

The form of stereoscope most in use, consists of a box provided with two lenses, or rather two half lenses, placed apart, at a distance equal to that which exists between the axes of the two eyes. Two pictures taken with the necessary difference of angle are placed at the bottom of the instrument, and on

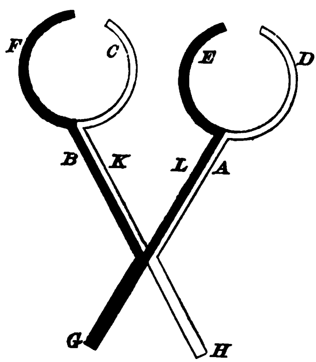
looking through the lenses one picture alone appears, standing out in relief.

Suppose that in the accompanying figure A and B represent the eye-pieces of a stereoscope; it will be seen that each glass consists of half a double convex lens, or that, in fact, each is a prism, the two being placed with their bases directed outwards; let C and D represent the two pictures on the slide at the bottom of the instrument; rays of light proceed from each picture to the under surfaces of the lenses, and passing through them, reach the eyes; let C F represent a ray coming from the picture C, and proceeding in a right line C F, till it meets with the lens A, and passing through that lens or prism, follows the ordinary law of refraction, being bent towards the thicker part of the prism, and enters the eye in the direction A H. In like manner, the ray D M from the point D is refracted by the prism B, and enters the eye applied to that lens in the direction B K; but the eye looks for the object from which a ray of light proceeds in the direction the ray impinges on the retina; therefore, the eye applied to the prism A sees the picture C at the point G, and in the same way the other eye sees the picture D also at the point G; therefore, the two pictures are seen superimposed, and the conditions being fulfilled, the idea of solidity is conveyed to the mind. Thus we see how, by the aid of an optical instrument, two images are combined, so that the appearance of reality is conveyed to the mind; but when objects are viewed with the eyes, unassisted, an image of any *single* external body is depicted on each retina, but



the mind recognises the presence of the *one* object only, because the rays of "visible direction" are referred to one spot, at which point either eye looks for the body from which the rays proceed, so that the images seen by both are superimposed, and one impression communicated to the brain.

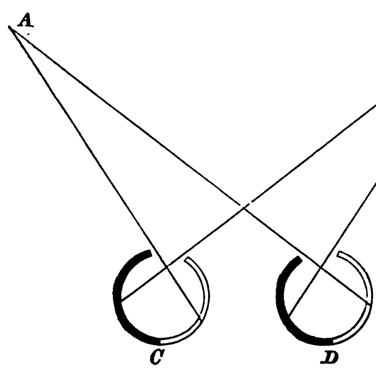
Before leaving the subject, a few words will be necessary respecting the transmission of impressions from the two retinæ to the nervous centre. It will be remembered that a decussation of the fibres of the optic nerves takes place in the optic commissure, and that the optic tracts are made up of fibres from both nerves; but it appears that the fibres which enter into the composition of the right optic tract proceed from the outer part of the left nerve and from the inner part of the right; in the same way, the left tract is made up of fibres coming from the outer part of the right and inner part of the left optic nerve. To facilitate the explanation of the relation that the expansion of the fibres in the retina have to the optic nerves and tracts, let it be supposed in the subjoined diagram, that A L and B K represent the two optic nerves, and G and H the optic tracts; the retina, being an expansion of the optic nerves, is represented at F C and E D; if, then, it is admitted that the fibres from the inner part of the retina F C are merely an expansion of the inner part of the optic nerve B K, and if the outer



fibres of the retina E D are connected only with the outer part of the optic nerve A L, it is clear that as the fibres from the inner side of the nerve B K

and the fibres from the outer part of the nerve A L together form the tract H, the two sides of the retinæ, C and D, are both in communication with the tract H, and, therefore, impressions received on the inner part of the left retina and on the outer part of the right are transmitted along the right optic tract to the right side of the base of the brain. In the same way, impressions on the opposite portions of the two retinæ are transmitted along the left tract to the left side of the brain.

If such is the actual arrangement of the nerve-fibres, it would appear that rays of light proceeding from an object viewed by both eyes would fall on those portions of the retina which are connected with the same side of the brain; at least, this would be the case with objects when near the eye. Thus, in the following figure of A is an object from which rays



proceed to the eyes, C and D; they fall on the inner and outer sides of the two retinæ respectively; in like manner, rays from the point B will fall on the inner and outer sides of the retinæ, but on the opposite sides or eyes; and, therefore, it may be that the impressions being united or strengthened by their trans-

mission through the same optic tract, produce but a single impression on the brain.

Adjustment of the Eye to different distances.

A camera is provided with a sliding tube, by means of which the lens can be shifted, so that the focus may be altered according to the distance of the object to be viewed; the back of a camera is also movable, and capable of being adjusted to the focus. It is obvious that some analogous arrangement must exist in the human eye, by means of which the focus of rays of light, from both distant and near objects, is always made to fall on the retina; but the exact nature of the mode by which this is accomplished is uncertain. Some physiologists imagine, that the dilatation or contraction of the pupil is sufficient; others, that the muscles of the eyeball press on and elongate the globe, thus altering the position of the retina. The correctness of either supposition is, however, very doubtful; the pupil does, it is true, contract when the eye is directed on an object at a long distance off, but in all probability another change in the interior of the eye also takes place, namely, a change of position or of form of the crystalline lens, which is supposed to be moved by the ciliary muscle. In favour of this view it is stated that predaceous birds, which are distinguished for their great range of vision, have very powerful ciliary muscles; moreover, the loss of the power of adapting the eye to distances, when the crystalline lens has been removed in the operation for cataract, speaks strongly in favour of this theory.

Duration of Impressions on the Retina.

When an impression has been communicated to the retina, it continues to exert its influence for a short time after the impressing cause has ceased to exist.

Thus, when a stick is whirled swiftly round with an ignited point, a circle of fire is seen, as the impression conveyed to the retina continues to act till the point of the stick comes round to the same spot again. On this principle, the thaumatrope and phenakistoscope combined a series of figures rapidly presented to the eye. Impressions caused by rays of light falling on the retina continue for 0·34″ or nearly a third of a second, but different-coloured lights vanish with different velocity.

Many natural phenomena depend on this property of the retina; for example, the eye connects the varied movements of the electric fluid in forked lightning, and though this is the successive impressions of numerous separate discharges, yet the eye connects the whole course into a forked line. The use of this property of the retina is evident, for unless this power of retaining the impression for a short period existed, at every act of nictitation vision would be obscured.

The act of winking has been previously alluded to, and its use in spreading the tears over the conjunctiva mentioned. It serves yet another purpose; no nervous action can continue without moments of cessation, and a brief period of rest is afforded to the retina at every fall of the eyelid.

The impression of colours on the retina is peculiar; if any one colour is strongly impressed for a considerable time, on its sudden withdrawal the complementary colour will be vividly depicted, or rather a sensation will be communicated to the brain such as would be produced by the presence of the second colour. Thus, if the eye rests on a bright *red* spot for some time, when it is suddenly withdrawn a *green* spot of the same shape seems to take its place.

EYES OF THE LOWER ANIMALS.

IN many of the lower types of animals no approach, even to a rudimentary eye, can be detected; but in some creatures that rank rather higher coloured spots are found to exist, which, from the nervous filaments connected with them, may be regarded as optical organs.

The *Echinodermata* is the lowest animal in which any such spots have been discovered.

Mollusca.—No advance in the complexity of the structure of the eye presents itself in the lower Molluscs; but in some of the higher classes, especially amongst the Encephalous, an advance in the development of the visual organs is observable. Thus, in the Cephalopoda eyes are found which contain almost all the characteristic parts of the eyes of higher animals. The eye of a cephalopod has a distinct cornea, crystalline lens, and vitreous humour, an anterior and posterior chamber filled with aqueous fluid, and also the three external coats—sclerotic, choroid, and retina. The connection of the organ with the brain, however, is remarkable; instead of a single optic nerve passing from each eye, numerous nervous filaments connect the retina with the optic ganglia which are situated close behind the eyeball. Though the other parts of the organ are so similar to those of the higher animals, a complete iris is wanting, being represented only by a rudimentary fold of the sclerotic.

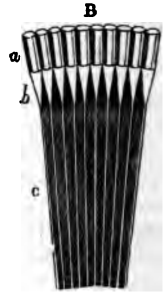
Articulata.—In the lower ranks of this sub-kingdom the eyes are of a very rudimentary character; but in the higher types, as in insects, the visual organs are greatly developed. In most *insects* the eyes are *compound*, that is, each organ is made up, as it were, of a number of separate eyes, clustered together into one mass, each presenting a distinct cornea, breaking up the whole surface of the compound eye into a number of facets. Insects are provided with two compound

eyes, which are usually large, forming a hemispherical protuberance on either side of the head. On examining one of these eyes, the surface presents several thousand facets, each of which is the cornea of a distinct simple eye. On section of the compound eye, it is found that the whole mass is made up of these simple eyes, placed in a radiating manner, each consisting of a pyramidal-shaped crystal body, at the upper part of which is the cornea or facet, and at the lower a fluid, vitreous humour. Each simple eye, moreover, is coated at its lower part with a black pigment, so that rays of light entering it do not interfere with those passing into the adjacent tubes. At the base of these

A

The Eye of an Insect: A, section of the eye; B, a portion more highly magnified; *a*, cornea; *b*, pyramids; *c*, *d*, optic nerve.

B



The Corneæ and Crystal Pyramidal Bodies, coated with pigment, more highly magnified.

pyramidal-shaped bodies is the expansion of the optic nerve, which receives impressions made through any one of the simple eyes. Each facet is, as before stated, a cornea, which, when closely observed, is found to be bi-convex, acting as a lens, and the pigment at the lower part of each cone prevents any divergence or refraction of the rays in their course to the optic nerve. It is evident that, as all the simple eyes are arranged in a radiating manner from a common centre, each one must have a very limited range of vision, but

that the whole compound organ is capable of taking in an extended view.

Crustacea possess eyes very similar to those of insects, but the organs are smaller in proportion to the size of their bodies.

Arachnida, too, are provided with smaller eyes, but constructed in a similar manner; the number of simple eyes making up each compound organ, never exceeds eight, and these are not always collected into one mass.

Vertebrata.—Animals in the vertebrate sub-kingdom are furnished with distinct eyes, two in number, differing but little in form and structure from those of human beings. The visual organs of all vertebrata are spheroidal, enclosed by a sclerotic coat, lined with a choroid membrane, and provided with an expanded retina; in front is the cornea, behind which is the anterior chamber, crystalline lens, and vitreous humour; from the back of the organ passes a *single* optic nerve, connecting it with the ganglia at the base of the brain. Though the general arrangement is so similar to that of the eye in man, various differences present themselves in the several classes.

Fishes.—The eyes of fishes are remarkable for the great density of the transparent media, and the spherical shape of the crystalline lens; and also for the presence of a small body called the choroid gland, situated at the back part of the eyeball. The cornea of a fish's eye is usually flattened, and the sclerotic is either cartilaginous or bony, assisting in preserving the form of the eye. The quantity of aqueous humour is scanty, but the spherical crystalline lens is composed of a very dense structure, so that rays of light are refracted by it, and brought to a focus soon after passing through its substance. As the water is itself a dense medium, it is absolutely necessary that the lens should be still more dense, in order that the light entering the eye should produce an image of external objects, depicting them on the

retina. The retina is plicated, or folded like a fan, and in the cod it is folded up before entering the organ, expanding after it has pierced the sclerotic. The choroid gland is a vascular erectile body, placed at the back of the eye, and supposed to assist in adapting it to different distances. The choroid membrane itself is composed of three layers, one of which has a bright metallic lustre. The eyes of fishes being placed on opposite sides of the head, cannot be brought to bear on the same object at one time, and it is found that the optic nerves proceeding from the back of the eyes pass directly across to the optic ganglia, without decussating in a commissure.

Reptiles.—In this class the eyes present but a rudiment of the osseous or cartilaginous plates in the sclerotic, except in the extinct species, in which the front of the eye is often protected by distinct bony plates, as in the Ichthyosaurus. An arrangement of the skin is now first observed, by means of which protective flaps are produced, covering the front of the visual organs, and forming the eyelids. In serpents, however, the skin is continued entirely over the cornea, becoming transparent as it passes over.

Besides the external lids, a rudimentary third eyelid, called the membrana nictitans, is developed at the corner of the eye; but, in Batrachia and Sauria, a complete nictitating membrane exists.

Birds.—The eyes of birds are more perfectly developed than those of any other animals, being larger in size, and adapted for very accurate as well as very distant vision. The general structure of the eye is similar to that of mammals, presenting, however, certain modifications; the shape of the eyeball is globular, being retained so by a sclerotic, strengthened by either osseous or cartilaginous plates, usually placed in front, to the number of twelve to sixteen. The cornea is very convex, and the anterior chamber large, containing a considerable quantity of aqueous

fluid. At the back of the organ is the *pecten*—a vascular body, which projects forwards, behind the retina, near the optic nerve; its use, probably, being to push the retina forwards, when the eye has to be adjusted to different distances—a function, which is performed by the pecten suddenly becoming gorged with blood; and being thus enlarged, pushing the nerve membrane before it. Two eyelids, of which the lower is the more movable, protect the eye; besides these, a completely developed membrana nictitans exists, which, when drawn over the cornea, sweeps off any dust on the surface of the eye, and, at the same time, moderates the light passing into the organ. Thus, by the aid of this semi-transparent membrane, eagles are enabled to look at the sun, at least, such is the common notion.

Mammals.—The eyes of mammals are smaller in proportion to their bodies than those of birds, and are destitute both of the protective plates on the sclerotic and the nictitating membrane, which is present only in a rudimentary form; in the human eye the small red fold of membrane at the inner angle is the representative of the structure. In certain quadrupeds the choroid is partly lined with a layer of shining pigment of metallic lustre, which causes rays of light entering the eye to be reflected backwards and forwards, strengthening the impressions produced, and enabling animals to see almost in the dark. This membrane is called the *tapetum*, and exists in great perfection in the cat, giving the peculiar glitter to the eye of that animal when seen through the dusk. The description of the human eye already given will serve for that of mammals generally; the only exceptions that require notice are the ornithorhyncus and animals of the whale tribe; in the former, the sclerotic is protected by osseous plates; and in the latter the crystalline lens is spherical, resembling that of fishes.

THE SENSE OF HEARING.

THE ear is an organ adapted for collecting and receiving vibrations propagated through the air or other media. In the human ear, the waves of sound are received on a thin membrane, stretched out at the end of a bony canal, and transmitted thence by a chain of small bones to the interior of the auditory organ, where impressions are received on the terminal filaments of the portio mollis, or auditory nerve.

In man the ears, placed one on either side of the head, consist of two portions, an external and an internal; the first is the part exposed to view, which we commonly call "the ear;" and the second is a cavity in the temporal bone, at the side of the skull, containing the more complex parts of the auditory apparatus.

The *external ear* is somewhat cone or trumpet-shaped, destined to collect vibrations, and reflect them to the canal leading to the interior of the organ. The external ear, or *pinna*, as it is called, is composed of cartilage covered with skin, and attached to the surface of the osseous canal in the temporal bone. Each part of the pinna receives a definite name; for example, the central cavity is called the *concha*, and the lower, pendulous part is termed the *lobule*. The concha opens into a canal—the *meatus auditorius*—which leads to the internal ear; at the bottom of this meatus is a membrane closing its inner aperture, called the *membrana tympani*, or "drum" of the ear; this structure is placed obliquely as regards the axis of the canal, and consists chiefly of fibrous tissue. Behind the drum is a cavity in the temporal bone, termed the *cavity of the tympanum*, which communicates with the throat by a duct, at the lower part; this duct is partly osseous and partly membranous, and is called the *Eustachian tube*.

Within the tympanic cavity are three small bones, *the malleus*, *incus*, and *stapes;* the first so termed

from its resemblance to a hammer; the second from being like an anvil; the third because its shape is like a stirrup. These three bones are connected together; the incus, being in the middle, the handle of the malleus is attached to the inner surface of the membrana tympani, whilst the foot part of the stapes fits into a small opening—the *fenestra ovalis*—at the other side of the tympanic cavity.

The fenestra ovalis is closed by a membrane to which the stapes is attached, and leads to a cavity termed the *labyrinth*, so called from its complex arrangement. The labyrinth consists of three distinct parts, the *vestibule*, *semicircular canals*, and *cochlea*.

The *vestibule* is the central cavity of the labyrinth, communicating both with the semicircular canals and cochlea.

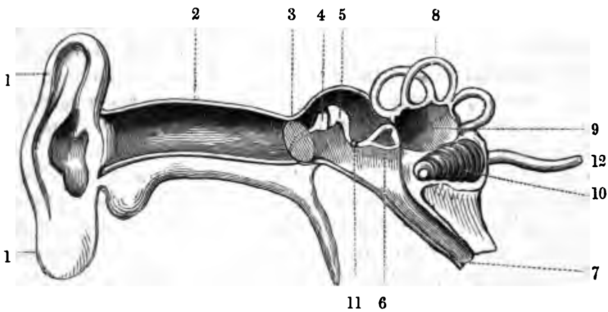
The *semicircular canals* are three bony tubes, arranged in planes nearly at right angles to each other, constituting the upper part of the labyrinth.

The *cochlea* is a portion of the cavity, being conical in form, resembling a snail shell, with a central axis or *modiolus*, around which winds a canal or *spiral tube*, making about two turns and a half round the axis. The interior of the tube is divided by a partition into two canals, which communicate only at the summit of the helix; but at the base they open by one aperture into the vestibule, the other opening leading to the tympanum. The whole labyrinth is lined with a membrane, which secretes a fluid called the "perilymph," except in the cochlea, where none is poured forth. In addition to this, two sacs of membranous structure exist in the cavity of the vestibule and semicircular canals; one sac is called the *utricle*, the other the *saccule;* the former sends prolongations into the semicircular canals. Both the utricle and saccule are filled with fluid, containing little particles of calcareous matter, called *oto-conia*, or "ear-dust." The whole cavity, therefore, of the vestibule and semicircular canals is filled with fluid.

The auditory nerve is a portion of the seventh cranial, and, after entering the internal ear, divides into two branches, one of which is distributed to the cochlea, and the other to the vestibule; the cochlea branch enters at the base of the modiolus, and is distributed to the interior of the spiral tube; the vestibular branch spreads out into filaments on the membrane forming the walls of the saccule and utricle.

Effect of Sound on the Ear.—The external ear, both from its form and position, is adapted to collect sounds from all directions, and to reflect them into the opening of the auditory canal. Sonorous undulations impinge on the membrana tympani, causing it to vibrate, the vibrations being communicated by the chain of bones to the membrane closing the fenestra ovalis, whence they are transmitted to the fluid in the interior of the labyrinth, producing certain impressions on the auditory nerve.

The membrana tympani is provided with delicate muscles, by means of which it can be tightened or



The Human Ear: 1, the external ear; 2, the meatus auditorius; 3, the membrana tympani; 4, the malleus; 5, the incus; 6, the stapes; 7, the Eustachian tube; 8, the semicircular canals; 9, the vestibule; 10, the cochlea; 11, the cavity of the tympanum; the figure points to the end of the incus, called the os orbiculare; 12, the auditory nerve.

relaxed; and the air is permitted to have free access to the tympanic cavity by means of the Eustachian

tube, the pressure on both sides of the membrane being thus equalised. When the Eustachian tube becomes blocked up by mucus, as is often the case in a common cold, the ear so affected is rendered deaf. In what manner the vibrations communicated to the fluid in the labyrinth act on the auditory nerve is uncertain; or what are the functions of the semicircular canals or cochlea is as yet unknown. Some imagine that as the canals are placed in different planes, the vibrations coming from different quarters are thus recognised. The otoconia is a rudiment of certain bodies called *otolithes*, found in the ears of the lower animals, and perhaps assists in intensifying sounds. The loss of the sense of hearing may depend either on lesion of some portion of the auditory apparatus, or on some disease of the brain or auditory nerve.

The Organ of Hearing in the Lower Animals.

The *Acalaphæ* are the lowest order of animals in which any signs of an aural apparatus has been detected; but in these, and in most *Molluscs* and *Articulata*, the organ of hearing consists only of a simple sac, with filaments of the auditory nerve distributed to its membranous wall, and one or more calcareous bodies, called *otolithes*, enclosed in its cavity.

All *Vertebrate* animals, with the exception of the amphioxus, are provided with organs of hearing; but even in some of the classes of the sub-kingdom, the ear is very rudimentary.

Fishes.—In certain fishes—the lower types of Cyclostomi—there is but little advance over the simple arrangement of a sac containing fluid and otolithes; but in the higher orders, semicircular canals are developed, and the ear, instead of being completely shut up in the bones of the skull, has an aperture leading to the exterior of the body, closed only by a thin membrane. In orders of a still higher rank, a distinct tympanic cavity exists, and even a rudimentary Eu-

stachian tube connected with the swim-bladder; the otolithes also are commonly large and well developed, composed of carbonate and phosphate of lime, and situated in the cavity of the vestibule. A pair of these curious bodies is usually present; their shape is somewhat irregular, but the edges are serrated, and in the body they are cemented together by a sort of mucus.

Reptiles possess ears of a more complex structure, containing a true tympanic cavity and membrane, with the chain of small bones, and even a rudimentary cochlea.

Birds.—The organ in birds presents a still greater advance, the cochlea being completely developed, consisting, however, of a straight instead of a convoluted tube.

Mammalia.—In mammals, an external ear is added to the internal structure—an addition which is found in no other class, except, indeed, in a few nocturnal birds; but in some mammals this external portion of the auditory apparatus is greatly developed, and is moved at pleasure by three muscles attached to it. The description of the human ear will apply to mammals generally.

THE PRODUCTION OF SOUNDS BY VARIOUS ANIMALS.

The production of sound is common to most of the higher, and also to some of the lower animals; but no creatures of simpler organization than molluscs are capable of emitting sounds.

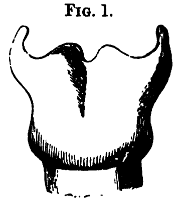
In the human being, the organ of the *voice* is situated in the upper part of the windpipe, called the larynx; and the organs of *speech* in the cavity of the mouth, the production of musical tones depending on the rushing of air through a narrow aperture—the

glottis—the edges of which are formed by two elastic vibratile cords, or *chordæ vocales;* and the production of articulate sounds, having no relation to the larynx, but depending on the transmission of a current of air through the oral cavity, and the movement of the tongue and lips.

The *larynx* is situated at the top of the trachea or windpipe, and consists of a tube formed by curiously shaped pieces of cartilage, which are connected by ligaments and membranes, and acted on by six small muscles.

The cartilages entering into the formation of the larynx may be easily felt in the throat; and one of them, which projects slightly forwards, especially in men, gives rise to an external swelling, known by the name of "the apple," or "pomum Adami." The cartilage that causes this projection is represented in the annexed figure, where a *front* view of the structure is given; it receives the name of "the *thyroid cartilage*," and is the largest of all the cartilaginous bodies that enter into the formation of the larynx. Below the thyroid is a ring-shaped cartilage, called the *cricoid*, narrow in front, but broad behind, attached to the thyroid by a membrane stretching in the space between the two, and also by two muscles situated at the lower part of Fig. 1.

FIG. 1.



Front view of the Thyroid and Cricoid.

The posterior part of the thyroid cartilage is open, and is occupied by the broad portion of the cricoid, and partly by two narrow horns of cartilage attached to the top of the cricoid. A posterior view of these cartilages is given in the following Fig. (2), where the two little horns, called the *arytænoid cartilages*, are seen rising above the cricoid, and connected together by muscular structure, the fibres of which are arranged crossways, constituting a muscle called the *arytænoideus.* A front and back view having been

studied, suppose a section made vertically through

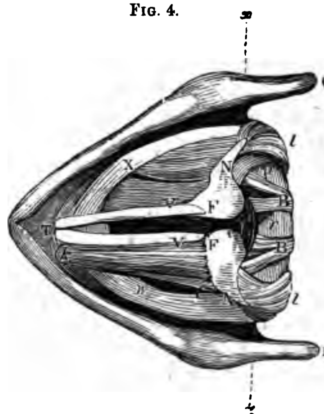
FIG. 2.

Posterior view of the Larynx: 1, 2, 3, thyroid cartilage; 4, cricoid; 5, arytenoid cartilage; 6, arytenoid muscle stretched out between them; 7, the crico-arytenoidei postici muscles; 8, epiglottis.

FIG. 3.

Section of the Larynx, showing the interior of the thyroid cartilage (1), the cricoid (4) being left entire; 9, the epiglottis; 2, 3, the arytenoid cartilages; 10, the trachea; 5, 6 7, 8, muscles.

FIG. 4.



View of the Larynx, as seen from above, showing the vocal cords (T V) and the opening between them called the "glottis;" G, E. H, thyroid; X, cricoid; N, F, arytenoid; *w*, *f*, *l*, *r*, &c, muscles.

the whole structure, as is represented in Fig. 3. Another muscle comes into view, running from back to front, from the arytænoid cartilage to the top of the inner surface of the thyroid; and it is evident that if this muscle contracted, it would draw the two cartilages nearer each other. In the same position, running below the muscles from back to front, are two cords which meet in

front, but are wider apart at the back, forming a V-shaped opening between the two. On looking down, therefore, from above into the larynx, these two cords, which are termed the *vocal cords*, may be seen as represented in Fig. 4. Through the narrow opening between them, the air rushes from the lungs, and according to the action of the little muscles attached to the cartilages, so are the vocal cords tightened or relaxed, and tones of different pitch produced.

All the muscles of the larynx have not been noticed, but it will be sufficient to state that there are six special laryngeal muscles—three internal and three external. The cartilages, too, are so fixed together by ligaments, that they can move on each other as on hinges; and above the vocal cords are lateral pouches and bands of ligament, forming what are called the *false* vocal cords. Besides these, just behind the root of the tongue, and at the orifice of the larynx, is a piece of yellow, leaf-shaped cartilage, called the epiglottis, connected with the upper part of the laryngeal cartilage and back of the tongue. This structure stands erect during respiration, but in deglutition it shuts down like a lid on the opening into the larynx, preventing the passage of food into the windpipe.

The nerves distributed to the larynx are two in number, on each side; one supplies the mucous membrane which lines the entire apparatus, and the other is distributed to the muscles; this latter nerve being a branch derived from the pneumogastric.

Air forced from the lungs through the windpipe, passing between the vocal cords, sets them vibrating, producing notes differing in pitch, according to the approximation of the cords and the power with which the muscles tighten and fix them in position. As the vocal cords are but about an inch in length, it is evident that there is no very great analogy between them and the common strings of musical instruments; for no ordinary string of so short a length could be made

to produce notes so clear and deep as some of those in the human voice. But a closer analogy exists between the arrangement of the laryngeal membranes and vocal cords to that of reed instruments; indeed, an artificial larynx and glottis has been constructed of a wooden pipe, like an organ pipe, at the upper part of which a fold of leather doubled round a peg served to represent the vocal cords; and, by means of this apparatus, sounds very similar to those of the human voice have been produced.

Speech, or the production of articulate sounds, consists of a modification of laryngeal tones by the agency of the tongue, palate, and lips; but distinct words may be produced without any assistance from the larynx—as in a whisper; the only condition necessary being the propulsion of air through the oral cavity.

Sounds produced by the Lower Animals.

As before stated, no animals lower than certain *Molluscs* are capable of emitting sounds; but many creatures in the *Articulate* series, especially amongst the *Insect* tribes, have the power of producing various kinds of sound, as humming, chirping, hissing, &c., either by a rapid movement of their wings, or by the friction of their limbs or antennæ against their bodies, or lastly, by the vibration of small plates of membrane situated at the extremity of the posterior spiracles of the chest.

VERTEBRATE animals possess the power of creating sound in a high degree.

No species of *fish* are known to produce sound except by the act of "blowing."

Reptiles are usually able to emit sounds; thus, the frog "croaks," the serpent "hisses," and crocodiles give a loud, harsh cry, almost amounting to a "roar."

Birds are characterised specially by the powerful voice they possess and the loud, clear, musical tones

they produce; but the arrangement of the larynx differs from that of the human being; and even in the various tribes of birds, different arrangements exist. Besides an upper laryngeal apparatus, somewhat resembling that of man, an inferior larynx or special organ for producing musical notes, is situated at the lower part of the trachea, just where it divides into bronchi; at this spot a transverse piece of bone with a vertical plate of membrane attached, is so placed that air passing from the bronchial tubes rushes up on either side and sets the membrane vibrating; moreover, each of the bronchial tubes has its own glottis, and the membrane stretched between the rings of the air passages, in this part of their course, is so tense that it acts as a sort of drum, increasing the loudness of sounds produced by the larynx.

But few birds are capable of articulating words, and those that do possess the power use the tongue in speaking.

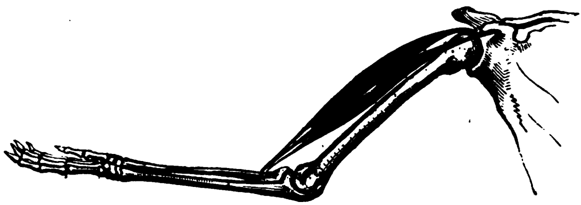
Mammals are all capable of producing sounds, and the structure of the laryngeal organ in almost the whole class resembles that of man.

ANIMAL MECHANICS.

Considering the animal frame as a machine destined to perform certain movements, it is obvious, that the bones forming the internal skeleton are the organs which afford fixed points of attachment and support; moreover, a greater or less degree of movement is permitted by the various articulations, when the muscles attached to the bones entering into the formation of these joints are called into action. The different forms of joints have been already described, our attention, therefore, may now be directed to the

manner in which the muscles act on the bones themselves.

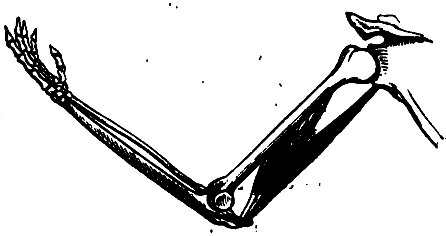
On examining the arrangement of the muscles in the human subject, it is found that they are stretched out between two osseous points, connected more or less to the bones from which they *arise* and into which they are *inserted*. Speaking generally, the muscles act at a mechanical disadvantage, as the manner of their attachment to the bones converts the latter into levers of the third order; for example, take the "biceps" muscle of the arm, its two upper



Biceps of the Arm.

tendons are attached to the scapula or shoulder blade, and its lower tendon is inserted into the radius (one of the bones of the fore-arm), just below the bend of the elbow. The elbow joint, therefore, is the fulcrum; and the bones of the fore-arm the lever; the weight, or resistance, is the hand and fore-part of the arm; the power supplied by the contraction of the biceps, acts at a point between the elbow and the hand; thus, a lever of the third order is produced; but, of course, the muscle acts at a disadvantage, rapidity of motion being gained at the expense of motive power. Many, nay, most of the muscles of the body, act in this way. We may also examine the disposition of the *triceps* at the back of the arm; an example of the first order of levers will be then found. Thus, the elbow joint is again the fulcrum, and the ulna the lever; the triceps is inserted into the upper part of the ulna, *called the* olecranon, which forms the short arm of

the lever, the longer arm being constituted by the



Triceps Muscle at the back of the Arm.

remaining portion of the ulna. Here, again, there is a loss of power, on account of the force being applied to the short arm of the lever. Lastly, an illustration of the second order of levers may be taken. The tendo Achillis is inserted into the os calcis or bone of the heel, raising the body by lifting the back of the foot in walking; in this case, the toes represent the fulcrum, the weight impinges on the foot at the point where it joins the tibia or bone of the leg, and the power is applied at the extremity of the heel. Here we have a gain of power consequent upon the fact that the power is applied to the longer arm of the lever, whilst the weight acts on the shorter.

There is still another method in which the power of muscles is partly lost. As a rule, they act in a direction nearly parallel to the axis of the bones which they move; this is the case of the deltoid muscle on the shoulder, which acts in the direction B A (in the following

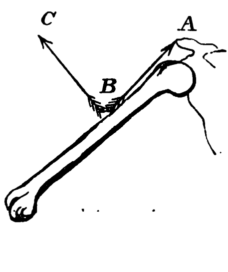


figure), and, therefore, does not apply its contractile force with the same advantage that it would did it act at right angles to the bone, in the direction B C. However, as the ends of the bones at the parts forming joints are usually enlarged, the muscles do not begin to act quite in the same line as the axis of the bones, but in a direction slightly oblique.

Either extremity may become the fixed point in muscular action, so that a great variety of movements is the result.

The tendons attached to the extremities of muscles, are guided in the direction of their destination, by grooves in the bones, or by strong sheaths of membrane, and occasionally by complete canals or rings of osseous and cartilaginous structure, through which they pass as through a pulley. Thus, the superior oblique muscle of the eye, passes through a small cartilaginous ring or pulley; and the tendons running down behind the inner ankle to the sole of the foot, have regular furrows hollowed out for them in the bones. There is but little friction in all the movements just referred to, owing to the presence of smooth articular cartilage and synovial fluid; at the same time, the joints and tendons are retained in apposition by strong ligamentous bands.

The human frame is constantly in danger of being exposed to external violence; certain provisional arrangements to guard the more delicate structures, therefore, exist. A good example of this is manifest in the arched form of the cranial bones, and the increased thickness of those portions most exposed to injury from direct blows. The form of the skull assists greatly in strengthening the structure, enabling it to resist even a very considerable degree of violence without fracture of the bones.

The spinal column, also, exhibits a marked provision in its arrangement, for protecting the enclosed cord, and for preventing the transmission of violent *sudden* shocks to the base of the skull and brain.

The various curves assumed by the whole column assist in resolving forces communicated to its lower extremity; and the elastic substance between the vertebræ carries out this plan still farther. Thus, in leaping, the violence of the shock to the feet is transmitted to the base of the skull, but the force is greatly diminished by its passage upwards through the legs and spinal column.

DEVELOPMENT.

ALL living beings, whether plants or animals, commence their existence in a simple form, becoming gradually developed and at length completely organized. If we go back to the earliest stage, we find that plants and animals alike originate from a simple cell, which, by its repetition and multiplication, constitutes in time the different parts of the organized being. In the earliest stages of development, we cannot distinguish whether the first primitive cell is that of a plant or an animal; and even when the progress of formation has continued further, and it is evident that an animal is being developed, it cannot be determined, to what sub-kingdom it will belong; and again, when the development has advanced so far that it can be distinguished whether the creature will be a radiate, articulate, molluscous, or vertebrate animal, the distinctive characteristic marks of the class in which it is destined to rank are wanting; nor is it till a still greater advance in organization has taken place, that the order and type can be surely determined. It must not, however, be imagined from this statement, that there is any analogy between the lower stages of development of the higher animals and the permanent form of the lower animals; or, in other words, that higher beings, in their development,

pass through a series of forms similar to the permanent forms of creatures of lower organization, or that, in fact, a higher animal can, as it were, be developed from a lower; for at no period of their existence (at least as soon as parts can be distinguished) do the higher animals present, in form and structure, a resemblance to the *matured* form or structure of animals of lower organization. It is true that some beings of the same class or sub-kingdom exhibit in their embryonic state a great similarity; but as development respectively progresses, so do the different parts in each animal assume a form less similar, and become adapted for the requirements of the special organism to which they belong. On the other hand, exception may be taken to these considerations; for it is equally true that animals of a high type may, in their earlier stages of development, be placed under such circumstances, that they resemble and live the same kind of life as animals whose organization is of a more simple type; the Batrachian reptile, the frog, in its earlier period of existence as a tadpole, resembles a fish in all important characteristics, habits, and arrangement of its vital organism; but at the same time, as development proceeds, the similarity to the lower type is lost and the hidden characters of the higher being present themselves.

An endeavour has been made by some writers to prove that a "progressive development" has taken place through all ages of the world, in such a manner that a regular gradation of organized beings has existed, which have become more and more developed and more highly organized in successive ages, by actual *transmutation* of the lower into the higher orders of living beings—a theory which, however ingenious, is not supported by our experience, and which receives no real confirmation from physiological facts; and without entering into an investigation of the possibility of such transmutation, it may be observed, that those intermediate links, which should properly exist

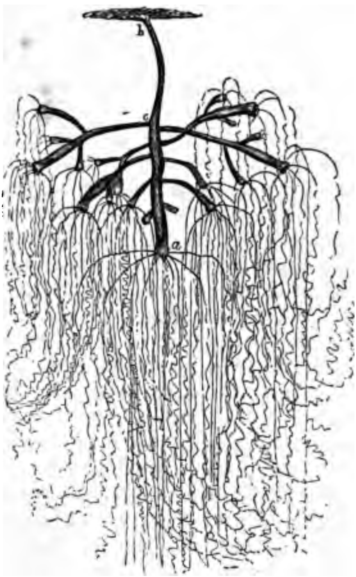
as distinct animals, as an evidence of transition from one type to another, are no where to be found; much less, then, can the idea be entertained, that animals were derived from plants, by the same "progressive" method of development as that by which one animal was said to be derived from another of lower organization.

The possibility, however, of a reverse process ever occurring, has yet to be determined—whether, in fact, an arrest of development of an animal of any higher type may give rise to a being of lower organization, which is capable of propagating creatures of its own kind, similar to itself in every respect. The external conditions and circumstances under which any organized structure is developed, certainly have a marked influence on its formation; a scanty supply of nourishment may thus prevent an animal attaining its full size; and it is well known that certain parasites found in the intestinal canal of animals, assume a different form and apparently different type, when transmitted from the body of one animal to that of another, though this change of form is really only an arrest or increase of development. Still, with respect to the "origin of species," it has been argued, that if the theory of progressive development be denied, fresh types must either have originated by a definite act of *creation*, or by *spontaneous generation* from inorganic matter acted on only by "physical forces."

Setting aside this question of primitive formation or origin of species, it seems to be an established physiological law, that every organized structure now originates in or from a pre-existing organized being; as set forth in the axiom, "Omne vivum ex ovo."

In the lowest forms of animal existence, in the *amœba* and *hydra*, a number of similar creatures can be artificially produced by mere fission or division of the animal's body; but a spontaneous multiplication of these beings takes place by the process of *gemmation* or budding.

On the body of a hydra a slight projection is first noticed, which gradually extends and, at length, produces a bud resembling in form the parent animal from which it springs. A free communication exists during the time, between the body of the original hydra and the bud; but when the latter becomes completely developed, the opening between the two is obstructed; and finally, the newly-formed hydra separates from the parent stem, and floats away as a perfectly independent animal.



A, hydra budding; *a*, head; *b*, sucker; *c*, buds.

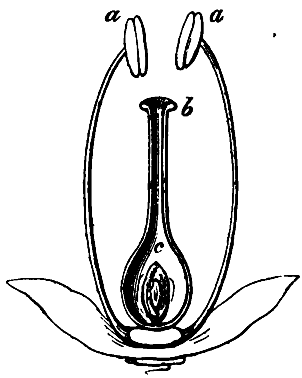
This mode of development depends on the multiplication of simple cells, by that continual subdivision already explained when speaking of cell-growth; and, indeed, in the gemmation of the hydra, the process is very extensively carried out; for several buds may arise at the same time from a single hydra; and even secondary buds may spring from the first before the latter are detached from the parent stem.

But though the power of reproduction from any cells forming the general mass of the whole body is observable in the cases just mentioned, in the higher animals, as a rule, the reproductive power is restricted to particular cells, formed and contained in a special

part of the organism; and we shall now find that the concurrence of *two* cells, and the amalgamation of their contents, is necessary for the production of a new being. One cell in this case fertilizes the other, and they are, therefore, respectively termed the "*sperm*" and the "*germ*" cell.

In all *plants*, except the very lowest, there is a distinct provision for the formation and subsequent meeting of the sperm- and germ-cells, the union of the two producing a new body termed the "embryo cell;" but in certain plants no difference between the germ-cells and sperm-cells can be detected, though in the higher orders a distinction is observable; the sperm-cells containing peculiar moving filaments.

The *pollen* of a plant consists of these sperm-cells, which, dropping off the anthers (*a*), pass down the pistil (*b*), and meet the ovules or germ-cells, which are surrounded by gelatinous matter, and contained in a chamber termed the "ovary."



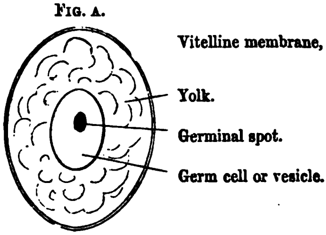
Reproductive Organs of a Plant.
a, a, anthers; *b,* pistil; *c,* ovary.

The union of the two cells then gives rise to the "embryo," which, with the gelatinous matter serving as a store of nourishment laid up round it, constitutes a *seed*. If placed under favorable circumstances the embryo cell divides and subdivides into numerous other cells, and becomes more developed, using up the store of nutritive material that surrounded it, till organs of assimilation are formed in its own organism, by means of which it can subsist on external matter and continue to progress in formation till it resembles the parents from which it originated.

In *animals* the reproductive process is somewhat similar. The sperm-cells contain moving filaments termed *spermatozoa;* and the germ-cells are surrounded with nutritive material, which together constitute what is called the *ovum.* The sperm-cells and germ-cells meeting (having existed, either in different parts of the body of *one* animal, as in hermaphrodites, or being supplied by *two* distinct animals, as is more commonly the case), the latter are fertilized by the former, and the fertilized germ-cells, together with the store of nutriment, constitute an impregnated ovum.

The nutrient matter of the ovum is termed the *vitellus*, or yolk, and is enclosed in a membrane called the *vitelline membrane*, or *yolk sac*. In the interior of the yolk is the germ cell, and, on careful examination, a small nucleus may be observed, which has received the name of the "germinal spot" (see Fig. A).

FIG. A.

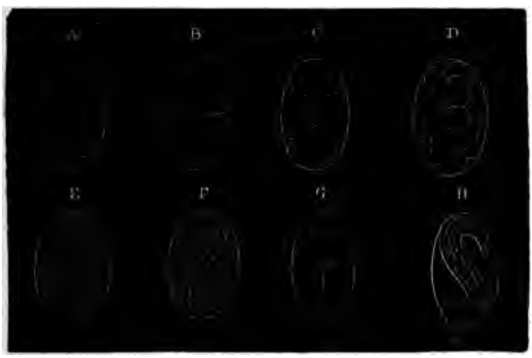


When the germ-cell, or, as it is usually called, the germinal vesicle, with its surrounding yolk and investing vitelline membrane, becomes matured and *fit* for fertilization, a number of cells spring from the germinal spot, and fill the interior of the germinal vesicle, which then bursts, permitting the contained cells to diffuse themselves through the yolk substance.

If, under these circumstances, a sperm-cell (the spermatozoa) comes into contact with this matured ovule, it pierces the vitelline membrane, penetrates into the enclosed cavity, and, becoming dissolved, mixes with the contained yolk, exerting a fertilizing influence, which causes a further development of the ovum.

A series of changes in the fecundated ovum now take place, termed the *segmentation* of the yolk. On examining the recently fertilized ovum of certain animals, where the investing membranes are transparent, there will be discovered in the midst of the contents of the vitelline membrane, a new formation, in the shape of a cell, called the *embryonic vesicle*, arising probably from the action of the dissolved sperm cell on some of the cells that were set free into the general mass of the yolk by the rupture of the germinal vesicle.

This embryonic vesicle, after a time, divides into 2, and then 4, 8, 16 new cells, and goes on subdividing in the same ratio, each new cell drawing round it part of the yolk, till at length the entire yolk-bag is filled with little globular portions of yolk, each of which contains a central cell or nucleus; and subsequently



Segmentation of the Yolk in the Ovum of a Worm.

A, B, C, D. commencing process of cleaving or segmentation of the yolk; E, formation of "mulberry mass" of cells; F, cells beginning to show the form of the future worm; G, H, the worm nearly mature.

each portion becomes invested with a proper cell-wall, so that the yolk-bag is filled with a mulberry-like mass of cells, from which the new being is evolved by further development.

The quantity of yolk present in an ovum varies greatly with the time that the embryo is destined to remain shut up in the egg. In the species where the young animal is developed into a form similar to that of its parents, before it emerges from the egg (as is the case with birds), a large store of yolk is laid up in the ovum, and we then find that the segmentation of the entire yolk does not take place; for the yolk divides into two parts, one portion alone becoming split up into segments in the manner just described, whilst the other remains unchanged, constituting a supply of food for the further development of the animal in the ovum.

The part of the yolk that becomes segmented may therefore be termed the "*germ-yolk*," and the remaining store of nutriment the "*food-yolk*." Thus, it appears that the period at which the newly formed being emerges from the egg varies in different animals, and depends partly on the amount of nutritive matter laid up in the ovum, some creatures issuing forth with the form they are destined to retain, others passing through a subsequent series of metamorphoses before their shape resembles that of their parents.

A general sketch of the process of development having been given, we may now proceed to consider the various methods of the process in some of the principal orders of the different sub-kingdoms.

Amongst the *Protozoa* the mode of reproduction is limited to that of fission and gemmation, and in the *Cœlenterata*, the same process is also observed, though occasionally multiplication takes place by the concurrence of sperm- and germ-cells.

In like manner the lower *Mollusca* and *Articulata* may be propagated, either by a species of gemmation or by development from a fecundated ovum; but in the higher orders of these sub-kingdoms the sexes are always distinct, and multiplication never takes place by budding.

Mollusca.—In the *Bryozoa* or lowest order of mollusks, reproduction by gemmation occurs in a manner similar to the process of budding in the hydra.

In the *Tunicata* multiplication takes place either by gemmation or by the more perfect method of development resulting from the meeting of sperm- and germ-cells. In the former case the process resembles that seen in the hydra, whilst in the latter the sperm- and germ-cells existing together in the same animal, meet and produce an ovum, in which a rapid segmentation of the yolk is first observed, followed by the development of a layer of transparent gelatinous matter round the whole mass, and a subsequent separation of the yolk into a body and a tail; and when the animal escapes from the egg it makes its appearance in a form somewhat resembling a tadpole. After a time the tail is thrown off, and by a farther process of development the organs in the interior of the body are produced, the external gelatinous coating becoming the outer tunic of the animal's body. Passing on to the higher order of mollusks, as the *Gasteropods* and *Cephalopods*, we find that propagation by budding ceases, and that all the animals either are hermaphrodite (that is, provided with both sperm- and germ-cells in the same body,) or diœcious (where the sperm- and germ-cells exist in separate animals). The development of the ovum is also much more complex in character, and a great variety of shapes are assumed before the individual takes its permanent form.

Articulata.—In the *Annelida* and lower types of the sub-kingdom Articulata, most of the beings included are hermaphrodite, and the propagation of the species by the process of gemmation frequently occurs, alternating with the more perfect method of development arising from the concurrence of sperm- and germ-cells. In the process of budding, a curious phenomenon is sometimes exhibited in Annelids; three

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The part of the yolk that becomes segmented may [illegible] be termed the "*germ-yolk*," and the remain[illegible] the "*food-yolk*." Thus, it [illegible] that the period at which the newly formed [illegible] emerges from the egg varies in different animals, and depends partly on the amount of nutritive matter [illegible] in the ovum, some creatures issuing [illegible] with the form they are destined to retain, others passing through a subsequent series of metamorphoses before their shape resembles that of their parents.

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or even four worms may be formed from one parent stock, so that a communication between the extremities of the four exists in such a way that the alimentary canal is continuous, the whole series being fed by one mouth till the animals are detached and assume a separate existence. In the higher orders of the sub-kingdoms, as the *Myriapoda* and *Insecta*, the process of gemmation is not observed, the animals contained in those classes being diœcious. Insects are evolved in a more or less perfect state from an impregnated ovum. On issuing from the egg, an insect is usually wingless, and is termed a *larva;* during the period the wings are becoming developed, the term *pupa* or *nymph* is applied, and when the creature obtains its perfect form, it is called an *imago.* In the ovum of an insect, a segmentation of the yolk is first observed breaking the whole up into cells in the ordinary manner; but at the external part of the yolk substance the formation of cells is excessively rapid, so that a kind of cellular membrane is produced from the outer portion of the vitelline mass. The cellular envelope thus formed is not completed at the part of the yolk which is destined to become the dorsum of the larva, but by a subsequent development of fresh cells the entire membrane is thickened and the yolk quite enclosed. An elongated mass of yolk, invested with an entire cellular membrane, is thus produced, and by a farther subdivision and development of the cells in the interior of the mass the visceral organs of the larva are formed, and by a thinning away of the investing membrane the apertures of the mouth and anus are produced.

The *larva* having been so far perfected in the egg, breaks the shell and issues forth in the form of a worm or maggot. During this period of its existence, it greatly resembles some of the Annelida, the body being segmented in a similar manner. A large supply of food is required by the animal whilst in this condition, and one or more exuviations or shedding of the

external skin commonly take place. The larvæ of some insects spin a cocoon of silk, in which they enclose themselves and become transformed into a *pupa;* but in other cases the precise time of change into the second stage is not so definite, no cocoon being produced; for, as the exuviations of the skin proceed, the wings and other organs peculiar to the imago are formed, so that at the last shedding of the skin, the insect assumes its permanent shape, and spreads out its wings which had previously remained folded up under the cast off skin. When a cocoon is spun at the last period of exuviation, the skin, instead of being thrown off, dries up and encloses the animal in such a way that it remains in a perfectly inactive state during the whole period of its existence as a pupa, and during this period which lasts a variable time in different insect tribes, the wings and other organs of the imago are developed, so that, on issuing from the old casing of skin, the insect appears in its perfect form, after which no farther change takes place till the animal dies.

Crustacea.—But little is known respecting the development of the ovum in the Crustacea; but it appears that a separation into a head and body occurs at a very early period, and when the animal issues from the egg, it possesses, in many orders, the form of its parents, though in others a series of transformations is gone through before it arrives at that state. Many crustaceans have the singular power of casting off their limbs when disturbed, and after a time of producing a fresh limb in the place of that which had been thrown off. This capability of reproducing lost parts is not confined, however, to this class; for insects in their larval condition also possess the same power of repair, and it would seem as though this method of re-development of any particular limb resembled, in some degree, the process of gemmation in the lower animals.

Arachnida.—In the class of spiders, the repro-

duction of species is confined to development from ova.

The ovum of a spider receives a coating of albumen, which becomes invested by a membrane termed the *chorion*. The separation of the vitelline substance into a germ-yolk and food-yolk takes place, the former undergoing the usual segmentation, an investing cellular membrane being produced by a rapid development of cells at the external parts, in a manner similar to that formed in the development of the ova of insects. After the completion of the investing membrane, several constrictions appear in the vitelline mass, separating it into a head, body, and segments, from which the various appendages spring. When the process is complete, the young animal escapes from the shell with a form similar to that of its parents.

VERTEBRATA.—No animals of the vertebrate sub-kingdom, are ever propagated by the simple process of budding, and even the capability of reproducing lost parts is extremely limited, especially in the higher orders, where the power is confined to the mere healing of the injured or amputated limb, without any attempt at redevelopment of the lost member.

Of the four classes of vertebrate animals, fishes, reptiles, birds, and mammals, it will be most convenient to begin with the description of the development of the ovum in mammals.

Mammalia.—All the animals of which we have been speaking are oviparous, that is, the young are born enclosed in an egg, from which after a time, they escape with a more or less perfectly developed form; but we now pass on to consider a class of animals in which the young are matured before birth, and are born with their various organs completely formed, undergoing no material alteration in shape afterwards. In the ovum of mammals there is no *food* yolk, the entire vitelline mass undergoing segmentation, so that the nutrition of the embryo is maintained by a peculiar

arrangement, by means of which the blood of the parent affords the required nourishment. The *human ovum*,* in the unimpregnated state, is very small, about $\frac{1}{200}$th of an inch in diameter; the yolk-bag or vitelline membrane, which is in mammals termed the *zona pellucida*, being about $\frac{1}{2000}$th of an inch in thickness, and quite transparent.

The ovum when in the ovary (or organ of the parent where the ova originate) is at first contained in a vesicle filled with albuminous fluid, called the *graafian vesicle*, the walls of which are made up of a layer of nucleated cells. In a fully formed graafian vesicle, the ovum is usually situated on one side, surrounded by a mass of cells, called the *discus proligerus*. The yolk or vitellus, is in most mammals thick and consistent, containing, embedded in its substance, the *germinal vesicle*, which consists of a very fine, structureless membrane full of clear watery fluid. At one spot in the periphery of this vesicle is a finely granular substance of a yellowish colour, called the *germinal spot*. It is very evident that if the ovum is so minute, the germinal vesicle and spot must be still more so; indeed, this last-named structure measures only the $\frac{1}{3500}$th of an inch in diameter. At certain periods, the boundary wall of the graafian vesicle bursts, permitting the ovum to escape; and if at this time, any spermatozoa come into contact with the ovum, impregnation takes place and further changes occur in its condition, leading to the formation and development of a new being.

The impregnated ovum now takes on a new action, and the changes that follow in the production of the embryo will next claim our notice.

The germinal vesicle first disappears, and the cells that formed the membrana granulosa, which adhere to the ovum after its escape from the graafian vesicle, are also lost. The ovum now leaves the ovary and passes down a tube, called the *fallopian tube*, to the

* The ovum is commonly called the *ovule* in plants.

uterus, or maternal organ, in which the subsequent development of the embryo is destined to take place. As the ovum passes down the fallopian tube, it receives a fresh investing substance, consisting of a layer of albuminous matter. This albuminous layer is quite transparent, and closely surrounds the zona pellucida; and by the time the ovum has arrived at the lower extremity of the fallopian tube, becomes very considerably thickened, forming, together with zona pellucida, a membrane termed the *chorion*.

The chorion, when fully formed, is a textureless membrane from which minute villous processes spring, and by means of which blood is first imbibed from the maternal structures for the support of the embryo.

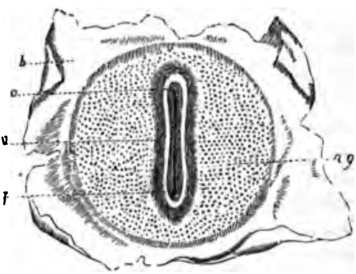
Besides the acquisition of the albuminous layer and the production of the chorion, during the passage of the ovum down the fallopian tube, a change in the condition of the yolk, also happens; it commences to divide and subdivide, becoming segmented and broken up into numerous cells in a manner similar to that previously described. So minute is this subdivision, that the yolk appears to consist of a finely granular matter after the cleavage has been completed. Subsequent to this, each of the segments of the yolk becomes invested with a membrane and converted into a cell; and at the external or peripheral part of the vitelline mass, the cells thus formed become developed into a membrane, which by a farther accretion of cells, increases in thickness, and constitutes an investing tunic for the vitellus, receiving the name of the *vesicula blastodermica* or *germinal membrane*.

During the time that had been occupied by the transit of the ovum from the ovary to the uterus, certain preparatory changes have occurred in the cavity of that organ, fitting it for the functions it is destined to perform in the farther development of the embryo. The mucous membrane lining the uterus becomes more vascular, soft, and tumid, pouring out

an augmented secretion, and forms a membrane called the *membrana decidua*, so that on the entrance of the ovum into the uterine cavity, it becomes embedded in the soft, deciduous structure. A direct means of nutrition to the growing embryo is thus afforded by the conjunction of the chorion and membrana decidua.

Having sketched the changes that occur in the ovum up to the period of the formation of the germinal membrane, we may proceed with the description of the development of the embryo.

At one part of the germinal membrane, a spot caused by the aggregation of cells is observed; this spot appears to be rather more dense than any other portion of the texture, and receives the name of the *area germinativa*. Soon a division of the germinal membrane into *two* layers takes place, commencing at the *area* germinativa; and a central clear space gradually appears in the area germinativa which is called the *area pellucida*. Surrounding the area pellucida, is an opaque band formed of an aggregation of cells, termed the *area vasculosa*.



The Germ, &c., from an Ovum.

a, g, area germinativa; *b*, germinal membrane; *c, q*, primitive groove; *v*, laminæ dorsales.

The germinal membrane being divided thus into two membranes, the external layer is called the *serous*, and the internal the *mucous*; from the former the bones, muscles, and integuments of the body are developed, and from the latter the visceral organs and internal parts are formed.

The first trace of the embryo exists in the serous fold of the germinal membrane, in the form of a

shallow groove in the centre of the area pellucida, and two masses of cells—the *laminæ dorsales*—one on either side. These masses extend and at length unite, enclosing the primitive groove, the inner portions becoming converted into nervous substance forming the rudimentary spinal cord and brain.

Whilst this process has been going on, numerous cells have been arranging themselves in a linear row directly beneath and parallel to the primitive groove, producing a basis round which the vertebral column is subsequently developed; and during this commencing development of the nervous centre and spinal column, the serous membrane sends off prolongations which unite and form the anterior walls of the trunk. Between the serous and mucous layers, a fresh accumulation of cells occurs in the area vasculosa, constituting a foundation for the development of the vascular system. The layers of the germinal membrane that extend beyond the extremities of the embryo then fold in under the part forming the abdomen, making a depression in the yolk; and at the under surface of the embryo, a channel now presents itself constituting a rudimentary alimentary canal, which gradually closes in, forming a tube shut off from communication with the yolk, except at one part where the closure is incomplete, termed the vitelline duct; this, however, also closes subsequently, shutting off the canal entirely from the yolk.

Up to this point the embryo has been nourished by absorption of the yolk substance, and it is now that blood-vessels first begin to appear in the area vasculosa, in the form of small red spots, that afterwards extend and become developed into capillaries.

The embryo being deprived of nourishment from the vitellus is hereafter supplied in a manner next to be described. By means of a reflection of the germinal membrane over the embryo, a new covering called the *amnion* is produced, and shortly afterwards there springs from the embryo itself a membranous prolonga-

tion, termed the *allantois*, in which the umbilical cord consisting of two arteries and a vein, is developed, and by means of which blood is carried from the maternal structures to the embryonic being.

It will be remembered that the tufts or villi of the chorion became imbedded in the membrana decidua lining the uterine cavity; blood-vessels subsequently becoming developed in the chorion and in its villi, are brought into communication with the embryo through the umbilical vessels developed in the allantois, which grows on till it reaches the chorion, and the spot where this junction takes place gives rise to a confined mass of blood-vessels, constituting what is termed the *placenta*. No direct communication between the blood-vessels of the placenta and those of the uterus exists, but the blood passes from the maternal vessels in the uterine walls into those forming the placental mass, by a process of transudation and absorption through the coats of the two sets of vessels. The uterine and placental blood-vessels, however, do not come into actual contact; for between them are two layers of cells, by means of which the required materials are abstracted from the maternal blood, and carried into the fœtal circulation.

Implacental Mammals.—Amongst the higher orders of mammalian animals the young are very perfectly developed previous to birth; but in the lower orders of the class the offspring, at the time of birth, are little advanced towards maturity, and require a special provision for their protection and support. This requirement is supplied (as seen in the Marsupialia) by the addition of a pouch, formed of a pair of folds of the integument covering in the mammary glands, so that subsequent to birth the young remain attached to the nipples, at first almost without the power of movement, but gradually acquiring strength and the capability of leading a separate existence.

We may now proceed to consider the development of the ovum in the remaining three classes—fishes,

reptiles, and birds. The animals included in these groups, being unprovided with any uterus or placenta, are oviparous, the young being retained in the shell for a longer or shorter period after birth. In some of the higher reptiles, however, as the viper and lizard, the young emerge from the egg in the very act of birth, so that they are, in fact, born alive.

Fishes are oviparous animals, but the development of the ovum is very similar to that just described in mammals, except that the nourishment supplied by the yolk continues to furnish the entire support of the embryo till it quits the ovum; and even after the newly formed being emerges from the egg no special provision for aërating the blood exists further than by a distribution of capillary vessels over the walls of the yolk-bag, which hangs attached to the abdomen of the young fish till the gills are sufficiently developed to carry on the respiratory function.

Reptiles.—The development of the ovum in reptiles* takes place without any further change of plan, except that the allantois extends itself round the yolk-sac, intervening between it and the shell, through which the air penetrates, thus having free access to the blood-vessels distributed in the allantois itself.

Most reptiles bring forth young resembling themselves at birth, but amongst the frog tribe the young animal, on quitting the ovum, appears at first as a tadpole, with a large head and long tail, leading the life of a fish, and breathing by means of branchiæ, which exist both externally and internally. The external branchiæ are soon lost, and the animal respires by means of the internal gills alone. As the tadpole increases in size, the tail either grows with the rest of the body, as in *newts* or *tritons*, or dwindles, wastes away, and disappears, as in the common frog. After the tadpole has continued in the form already mentioned, the hind feet begin to appear, and when they have attained some length the fore feet are developed;

* Except the frog tribe.

at least this is the rule with the tadpole of a frog, but in tritons the reverse occurs, the hind feet being developed last. After the animal has continued to respire with its internal gills, and has for some time been leading an aquatic life, lungs begin to be developed, and for a short period the reptile can breathe either by means of its gills or lungs; but as the lungs become completely formed, the gills disappear, so that in the adult no traces of them remain. The arrangement of the circulatory apparatus, of course, differs in the young and adult animal, as the mode of respiration is changed. In the young batrachian the blood is distributed by the heart to the gills, and thence passes to the great dorsal artery, being conveyed by the branches of that vessel to the various organs of the body; but in the adult animal the branchial arteries become obliterated, and the blood is distributed to the lungs and system much in the same way as in other reptiles.*

Birds.—The development of the ovum and embryo of birds, though carried on much in the same manner as in mammals, presents some peculiar features in the process.

The ovum of a bird, whilst passing down the oviduct (which leads from the ovary to the end of the rectum), becomes coated with albumen, as in other animals, and receives a double membranous lining, homologous with the chorion of mammals. At the lower part of the oviduct is a thick, glandular sac, that secretes the shell, which is formed by the calcification of a similar membrane, constituting a very perfect protection for the embryo. Lining the shell is the double membrane already referred to, the outer layer sending villous tufts into the shell substance, and at the obtuse end of the egg the two

* On account of the differences in organism between Batrachians and Reptiles generally, the Batrachia are ranked by the most recent writers as a distinct class, "Amphibia," and not included amongst Reptilia.

layers separate, enclosing a small bubble of air. Extending from either extremity of the yolk-bag to the ends of the shell, are two albuminous cords, termed the *chalazæ*, preventing the yolk from moving towards either end, but permitting it to turn on its axis.

The yolk is rather lighter than the albumen surrounding it, the latter being of a watery consistency, except just round the yolk-bag itself. In the ordinary condition of an egg the yolk floats near the side that is turned uppermost, and as it is permitted to move on its axis, the germinal spot, where the formation of the embryo first commences, always turns towards the upper surface, so that the growing embryo has the benefit of the heat derived from the body of the mother sitting on the egg, and receives the influence of the air that permeates the shell, aërating the blood-vessels in the allantois, which extends round the yolk-sac, as in reptiles.

In birds the yolk is divided, as in most oviparous animals, into the "germ" and the "food-yolk," the latter, forming the bulk of the vitelline mass, being destined to supply nutriment during the early periods of development. With regard to the subsequent formation of the embryo, it proceeds on a plan very similar to that observed in mammals, but the vitelline duct remains open in birds, affording a free communication between the rudimentary alimentary canal and the contents of the yolk-bag; and, as the yolk is gradually taken up for the nourishment of the embryo, the yolk-bag is itself drawn into the abdominal cavity.

DEATH.

MADE up, as the body is, of cells and fibres, it is evident that, if the reparative power remained perfect, and the constant waste to which all parts are subject in the discharge of their natural functions was provided for by a corresponding redevelopment of tissue, life might continue for an indefinite period, unless disease or some sudden injury to any of the more important organs occurred. But as every manifestation of vital activity is attended by an amount of impairment and change of condition of the organized frame, the body gradually deteriorates; in youth and manhood the waste and change of various structures are fully compensated for by a constant regeneration of tissue, but in advanced life and old age the power of repair slowly diminishes, till, at length, the organism becomes thoroughly deteriorated, all vital action ceases, and death ensues.

Death, then, would be the natural and inevitable consequence of life, supposing even that disease and injury could not assail the body; but death may occur at any age, from derangement of any of the more important vital organs or a disturbance of their functions. The cessation of life may result in different ways, from various causes; a deficient supply of blood to the brain or lungs, a loss of irritability and propulsive power in the heart, or a change in the condition of the blood, will produce death, each in a different manner. If, from any cause, the supply of blood to the brain is cut off, death by *syncope* is the result; if the action of the lungs is arrested, or the flow of blood in them impeded, death by *asphyxia* supervenes; if certain poisons accumulate in the blood, and the impure fluid circulates through the brain, or if blood escapes in the cavity of the cranium, or pressure is in any way made on the brain substance

death by *coma* occurs; and, lastly, when the heart's action is gradually weakened, and the quality or quantity of the blood reduced, death from *asthenia* takes place.

In death from syncope, where there is a deficient supply of blood to the brain, the primary cause of death may depend on a want of propulsive power in the heart, or on some obstruction in that organ, and this want of power may be frequently traced back to the nervous system; thus, a sudden shock to the brain, any violent mental emotion, may cause a failure of the heart's action, followed by an arrest of the flow of blood to the brain, and consequent death by syncope.

Death from asphyxia may result from any cause retarding the current of blood through the lungs; an obstruction in the heart on either side of its cavity, or an obstruction in the capillaries of the lungs themselves, may cause suffocation, and the same result may be produced by a continued privation of fresh air.

Death by asphyxia must be attributed to the accumulation of carbonic acid in the blood and the circulation of the impure fluid through the brain and other important organs, for cold-blooded animals, in a state of torpor, when the circulation is very slow, may be immersed in water for a considerable time without injury.

Death from asthenia can scarcely be said to be different from death from syncope, for certainly in an asthenic state of system syncope very readily takes place, and it is usually the cause of death in such cases.

Coma may be produced by the introduction of certain poisons, such as opium, urea, &c., into the current of the blood; it may also be induced by the rupture of a blood-vessel in the brain, and the escape of blood into the cavity of the skull, or by the pouring out of the watery part of the blood through the coats of the

cerebral capillaries without rupture of their walls; and, lastly, by the absolute pressure caused by a portion of the cranial bones driven in and compressing the brain substance.

Death by asphyxia would, therefore, seem to be death by coma; for, as before stated, suffocation produces death by causing impure blood to circulate through the brain.

Sudden death may be caused by severing the spinal cord above the origin of the nerves supplying the respiratory apparatus, or by dividing the trunks of those nerves on both sides. It has been asserted that in the medulla oblongata there is a point termed the "vital spot," which, if injured, produces instant death; this statement, however, wants confirmation.

Death having taken place from one of the above-mentioned causes, the body undergoes what is termed "molecular death," and, decomposing, returns to the elements of which it was formed.

The description of the anatomy and physiology of the human frame, and the leading variations in the lower animals, having been concluded, it is necessary to mention that in many parts of the account given the more refined or uncertain details have been omitted, and in many cases where different theories are held only one particular view has been carried out.

In the description of the divisions of the animal kingdom given in the first few pages, in one or two points the most modern method of classification has not been adopted, but that which appeared the most simple, and which, for the purpose of general arrangement, served equally well; for example, the Vertebrate sub-kingdom is divided into five, instead of four, great classes; the *Batrachian* Reptiles being classed under the name *Amphibia*, and Reptiles only including the three other divisions. In Mollusca, too,

the term Conchifera is usually abandoned, and the Lamellibranchiata and Brachiopoda distinguished as classes. Some minor variations in the lowest types also exist in the most recent arrangements; but as the sketch given at the commencement is not intended as a zoological guide, they were not noticed.

AN EXTENDED VIEW OF THE VERTEBRATE SUB-KINGDOM.

Class.	Order.	Examples.
Pisces	Cartilaginous	*shark, skate, torpedo, lamprey.*
	Osseous	*perch, mackerel, carp, pike, herring, cod.*
Amphibia	Perenniatæ	*proteus, axolotl, siren.*
	Urodeles	*newts, tritons.*
	Anoures	*frog, toad, rainette, pipas.*
Reptilia	Ophidia	*viper, rattlesnake, cobra, python.*
	Sauria	*lizard, chameleon, iguana, gecko.*
	Chelonia	*turtle, tortoise.*
Aves	Palmipeds	*penguin, petrel, albatros, swan, duck.*
	Waders	*heron, crane, stork, ibis, woodcock, ostrich.*
	Gallinaceous	*cock, pheasant, peacock, turkey, quail.*
	Climbers	*parroquet, cuckoo, woodpecker.*
	Passerines	*blackbird, linnet, swallow, lark, sparrow.*
	Rapacious	*eagle, vulture, falcon, kite, hawk.*
Mammalia	Monotremata	*ornithorhynchus, echidna.*
	Marsupialia	*opossum, kangaroo.*
	Cetacea	*whales, dolphin.*
	Pachydermata	*elephant, hog, horse, rhinoceros.*
	Ruminantia	*ox, sheep, goat, stag, camel, giraffe.*
	Edentata	*armadillo, ant-eater, sloth.*
	Rodentia	*rat, squirrel, lerot, beaver.*
	Carnivora	*cat, otter, badger, dog, bear, lion, tiger.*
	Cheiroptera	*bats.*
	Quadrumana	*apes, monkeys.*
	Bimana	*man.*

AN APPENDIX OF QUESTIONS

From the Examination Papers for the B.A. degree of the London University;* for the Master's and Pupil's Examination of the Royal College of Preceptors; also for the Preliminary Examination for the Royal College of Surgeons, as conducted by the College of Preceptors; and for the Oxford Middle Class Examination.

1. How does the nutrition of an animal differ from that of a plant? (B.A. Lond., 1853.)

2. Mention the chief alimentary principles which constitute the food of man, and describe the changes which they severally undergo in the process of digestion, explaining especially the part performed in that process by the different secretions discharged into the mouth, stomach, and intestine. (B.A. Lond., 1854.)

3. Give a brief description of the mouth, pharynx, and gullet, and explain the mechanism of swallowing. (B.A. Lond., 1855.)

4. Give an outline of the structure and arrangement of the heart and blood-vessels in mammalia, and describe the circulation of the blood in that class of animals. (B.A. Lond., 1855.)

5. What differences in the sanguiferous system and course of the blood are presented by the cold-blooded vertebrata?

6. By what evidence is the circulation of the blood proved to take place? (B.A. Lond.)

7. Enumerate the tissues which enter into the formation of a voluntary muscle. Describe the structure and arrangement of the muscles, their mechanical and vital properties, chemical composition, and uses. State briefly the condition and phenomena of muscular contraction. (B.A. Lond., 1857.)

* The papers for the B.Sc. London are the same as those set for the B.A. in Animal Physiology.

conditions do long and short sightedness depend? (B.A. Lond., 1860.)

33. Describe, in general terms, the globe of the eye, &c. (B.A. Lond., 1861.)

34. Give an account of muscular tissue. (B.A. Lond., 1861.)

35. Describe the structure of the heart, and the course of the circulation in a mammal. (B.A., 1861.)

36. What are the chief divisions of the animal kingdom? (Pupil's Examination, College of Preceptors, 1861.)

37. Describe the process of respiration in the higher animals. (Idem.)

38. Trace the growth of a bird from the egg to its perfect form. (Idem.)

39. What functions are performed by the following parts of the body:—the brain, the nerves, the muscles, the bones, the tongue, and the eyes?

40. What differences are observable in the structure of the teeth and of the stomach in vegetable-feeding animals, as compared with those which live upon flesh? (College of Preceptors, 1860.)

41. Describe the process of digestion in ruminating animals, and compare it with the same process in man. (Idem, 1860.)

42. Give the distinguishing characters of the principal groups of animals:—viz., protozoa, cœlenterata, annulosa, mollusca, vertebrata. (Preliminary Examination for Royal College of Surgeons.)

43. How are fishes distinguished amongst vertebrate animals? (Idem.)

44. To what classes, orders, and families, do the following animals belong:—the horse, the lion, the seal, the porpoise, the rat, the weasel, the eagle, the ostrich, the sparrow, &c.? (Idem.)

45. Arrange under their proper order, class, and sub-kingdom, the following animals:—The dog, the cow, the whale, the kangaroo, the cod, the oyster, the lobster, the beetle, the snail, the star-fish, the sea-anemone; and give, if you can, the scientific names of

these examples. (Master's Examination, College of Preceptors, 1858.)

46. What is "vital force"? (Idem, 1856.)

47. Describe the two systems of nerves, and the functions performed by each. (Idem.)

48. What are the constituents and properties of the blood? (Idem.)

49. State the principal points of analogy between plants and animals. (Idem, 1855.)

50. Describe the organs and mechanism of the voice. (Idem, 1855.)

51. What is the normal temperature of the human body? How is it maintained, and prevented from undue elevation? (Idem, 1856.)

52. How is the function of respiration carried on in man, in fishes, and in insects? (Idem, 1856.)

53. Describe what is peculiar in the digestive apparatus of a ruminant. (Oxford Middle Class Exam.)

54. Distinguish the structure of the heart, and the circulation of blood in fishes, reptiles, and birds. (Oxford Exam.)

55. Describe the transformations of a frog, or of a newt (stating which), in respect to the organs of locomotion and of respiration. (Oxford Middle Class Exam.)

56. Describe the transparent parts of the eye of a vertebrate animal, the course of rays falling obliquely on the pupil, and the muscular apparatus for adjusting the direction of the eye. (Oxford Exam.)

57. What differences are observed on comparing the brains of vertebrate and invertebrate animals? (Oxford Middle Class.)

58. Why are not whales classed with fishes, and bats with birds? (Oxford Exam.)

59. Explain the circulation of the blood, and what differences, in this respect, appear between warm-blooded and cold-blooded animals. (Oxford Exam.)

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